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AN

ESSAY

ON

SUSPENDED ANIMATION.

BY

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PHILADELPHIA:

PUBLISHED BY EDWARD PARKER, 178 MARKET ST.

WILLIAM BROWN, PRINTER.

1823.

PREFACE.

This Essay is conducted upon the following plan: The general nature and causes of Asphyxia are first detailed; the species from submersion is then considered; next, the mode in which its causes operate; for this purpose, Respiration, as the function more particularly concerned, is first introduced, involving the examination of the effects of the various gases; of animal temperature, and of death from cold. After this preparatory discussion, the cure of asphyxia from submersion, with that of its other species, is given; and a history of the progress of resuscitation, authors, and humane societies, with the necessary apparatus, concludes the Essay.

With regard to the manner of its execution, it consists of a simple detail of facts, collected from the best authorities, as well as from a series of experi-

ments, whose object was to develope completely, and establish upon certain foundations, the truth of what was already known, as well as to discover something new, and thus to deduce a correct pathology and rational mode of cure.

CONTENTS.

AN ESSAY

ON

SUSPENDED ANIMATION.

LIFE is suspended, when its functions cease, but can be renewed; and is designated by the terms Asphyxia, Trance, and Suspended Animation.

Its causes operate either directly or indirectly on the lungs, the organs in which it arises, and may be produced by the suspension, either of their mechanical, chemical, or vital phenomena.

When it is caused by the division of the eight pair of nerves, or of the upper part of the spinal marrow; by wounds in the chest; by a strong compression of the thorax and abdomen; a sudden injection into, or gradual accumulation of, fluid in the cavity of the chest; the mechanical pheno-

mena of respiration are first interrupted, the oxygenation of the blood is prevented, and asphyxia is produced.

When it arises from a removal of the air, as in a vacuum; or by its extreme rarefaction, as in the ascent of very high mountains; by submersion in water or noxious gasses; by artificial closure of the trachea, as in suspension by the cord; or by natural means, as in the pressure of tumors in the trachea, in the œsophagus, throat, larynx or mouth, obstructing the passage of air, or by mucous collections in the lungs, the oxygenation of the blood is impossible, and thus the suspension of the chemical phenomena of respiration becomes its cause.

By the diminution of the vital powers generally, as by cold; lightning; fever; small pox; hysteria; syncope; apoplexy; the oxygenation of the blood is with equal certainty prevented, and animation is suspended.

Pressure on the umbilical cord in tedious deliveries is also supposed to produce it.

The symptoms of asphyxia are slightly varied by these different causes. They, however, agree in their essential characters, the changes produced in the organs immediately concerned and necessary to life, the lungs, the heart, and the brain.

The most common causes of this disease are

submersion in water, suspension by the cord, and noxious vapours; as the first occurs most frequently, it will form more especially the subject of the following pages.

On Suspended Animation from Submersion in water.

When an animal falls into water it struggles violently, and attempts to inspire; expiration soon follows, and bubbles of air rise to the surface; the struggles become more violent, the animal rises again, and inspiration is again attempted; the contents of the thorax are expelled, and it becomes greatly diminished in capacity; deglutition is performed in these struggles, the animal swallows a small quantity of water; the pupils are dilated, the eyes protruded and glassy; the tongue and gums become of a leaden or livid colour, and death follows generally in the space of from one to four minutes.*

The pulse in fifteen or twenty seconds after

* Oswald on the phenomena of suspended animal life, p. 2, Phil. Ed. 1802.

submersion, in one experiment, became more frequent and weak, gradually increasing in fulness and becoming less frequent, till, in sixty seconds, it was slower by fifteen or twenty beats, and more full; it then gradually declined, and between two and three minutes it ceased altogether.*

Goodwyn describes the pulse as weak and frequent; the fulness, which follows, he does not mention:† After apparent death, in the space of from fifteen seconds to one minute, a violent and general convulsive motion takes place; it is regular, slow, and strong, sometimes remaining nearly five seconds, returning again at a very short interval, and repeated two or three times in every minute for the space of a quarter of an hour or more, generally for about ten minutes after the natural struggling has ceased.‡ The muscles of respiration are particularly concerned; gasping also attends it, and when the animal is removed from the water a deep inspiration is made, and succeeded in a few seconds by an expiration, rendering it probable, that these convulsions are in-

* Oswald on the phenomena of suspended animal life, p. 2, Phil. Ed. 1802.

† Goodwyn on the connection of life with respiration, &c.

‡ Oswald on the phenomena, and Kite's Essays and Observations, p. 119. 1795, Lond.

tended by nature to re-establish the functions of the lungs.*

According to my experiments, the symptoms of drowning, are; the animal is frequently perfectly still for some seconds after submersion; bubbles of air rise to the surface, forced from the lungs by the muscles of expiration; violent struggling succeeds; the eyes are turned upwards; the feet are moved directly downwards, pressing against the bottom of the vessel in order to force the body upwards,† and continuing between forty-five seconds and one minute; the motions and looks of the animal then become irregular, and are directed in no particular manner; the head is thrown about from side to side, the tongue is protruded; the animal gasps, gnashes his teeth, and attempts to swallow; the pupils become dilated; the eyes staring, protruded, and glassy; and finally some frothy water is ejected, the struggles ceasing in the space of from one and a quarter, one and a half, two and a half, three, and sometimes not till the fifth and sixth minute;‡ in one instance the heart was felt beating violently after

* Oswald on the phenomena, and Kite's Essays and Observations, p. 119. 1795, Lond.

† Expts. 3, 5, 6, 7, 8, 14.

‡ Expts. 1, 3, 10, 11, 12, 13, 8, 26.

four minutes immersion ;* the convulsive stretching and gasping continued for two, three, and four minutes,† but it never was observed after six minutes, the animal being entirely dead after that period.

The symptoms felt on submersion by persons, who have been drowned and recovered, are stated to have been great anxiety, giddiness and loss of sense or recollection; in one instance the person crept along the bottom to reach the shore; his senses failed; he was taken up for dead, and after recovery, gave this account.‡

In animals, the state of feeling is pretty certain after submersion; their violent struggles show their anxiety and pain; the period of the continuance of sense is exactly ascertained to be between three quarters and one minute from the sudden irregularity and convulsive distraction of their movements occurring at the end of that period, after successive systematic and well directed efforts to escape, evinced by§ their looking directly upwards, and pressure of the feet against the bottom of the ves-

* Exp. 9.

† Expts. 5, 6, 7, 8.

‡ Mem. of the Soc. inst. at Amsterd. &c. translated by T. Cogan, M. D.

§ Expts. 5, 6, 7, 8, 14.

sel, forcing the body towards the top of the water.

After submersion, the human body is cold, relaxed, swollen; the head bloated, the face disfigured; the colour leaden, violet, livid or black; the lips are sometimes enlarged, the eyes flaccid, distended, dim and partly closed; the teeth are set, the mouth and nose covered with froth; the tongue is blue, livid, swelled or protruded; the chest is raised; the abdomen tense, and the body is without pulse at the wrist or beating at the heart; sensibility, sense and motion are completely suspended, and if the submersion has been sufficiently long to produce absolute death, the limbs are stiff, sometimes though rarely flexible, and the sphincter ani is generally relaxed.

From the circumstance that anxiety is the first morbid symptom after submersion, it is evident, that the disease commences in the lungs; in consequence, the animal struggles violently, showing that the brain and organs of voluntary motion are next exerted; the heart beats with great agitation; giddiness and loss of recollection succeed, evincing the suspension of the action of the brain.

In consequence, the voluntary motions become next distracted and irregular, evinced in the gnashing of the teeth, protrusion of the tongue, and

convulsive gaspings, accompanied with irregular efforts to swallow : the thorax, abdomen and limbs are more or less agitated, proving that the brain, lungs and heart are all involved in the general convulsion of the system, which precedes death.

The lungs, then, primarily, and afterwards the brain and the heart, are the vital organs which are principally disordered: the other irregularities and morbid symptoms are only the result of the disease, which exists in them, as will be explained hereafter.

The symptoms of recovery, are, water issuing from the mouth and nostrils, accompanied with froth; feeble, irregular and convulsive efforts to breathe, attended with gasping, and occasional motions and spasmodic agitations in the limbs. The pulse beats at intervals, is small, quick and weak ; the face becomes less livid, sometimes distorted and violently convulsed ; a rumbling is heard in the bowels ; the breathing becomes more free, the pulse more regular, and a gentle perspiration softens the skin : vomiting sometimes takes place, and gradually a return of sense and motion: sometimes the person continues silent, dejected and listless for several days, with pains in the head ; in one case death supervened in one hour after recovery, by a recurrence of epilepsy.

Recovery from drowning is extremely irregular in its circumstances; it has been successful in the aged and the young; even children of two and three years have been resuscitated after submersion for one minute,* and in several for not more than five death has supervened, notwithstanding the greatest efforts to rescue them; youth has perished, old age has been saved;† some were restored after immersion for half an hour; one out of 600 cases after 45 minutes,‡ another after more than an hour,§ and two after an hour and an half. Old age, apoplexy, syncope, epilepsy, intemperance in eating and drinking, fasting, fatigue or debilitating and chronic diseases, have preceded and rendered submersion fatal:‖ the probability of recovery will be determined by the combination of circumstances which heighten or weaken the susceptibility to previous disease in the sys-

* Reports of the Hum. Soc. of London, case 264, quoted by Kite, p. 60. See Fowler's exp. and obs. relative to the influence lately discovered, p. 70. Edin. 1793.

† Cases 19, 276, quoted by Kite.

‡ Cases 103, 165, 350, 420, 547, also Cogan's Mem. of the Amst. Soc. quoted by Kite, p. 60.

§ Amer. Med. Record. vol. iii. p. 339. 1820. Annual report of Roy. Hum. Soc. 1803. Letters from Copenhagen, 1800.

‖ Kite, p. 61, 62. Lond. 1795.

tem: apoplexy is rendered probable by a short neck, a full habit of body, and from the occurrence of the submersion without violence or accident.

Frequent giddiness, nightmare, false vision, tingling in the ears, loss of memory, horrible dreams and unrefreshing sleep, will increase the probability that this disease had preceded. Affections of the lungs, long immersion in cold and deep water, or exposure, after the body is found, to rain and high winds, increase the danger. Recovery has followed submersion for fifteen minutes, though fainting had taken place immediately before; and cases are stated, on the most respectable, but now doubted, authority, in which submersion had existed for days, and the patients were restored.* In other species of asphyxia, resuscitation has taken place after interment; a lady, in England, was brought to life by a thief who attempted to steal a ring from her finger.† Sometimes dissection has produced resuscitation, as in the case of the earl of Pembroke, who, on being opened to be embalmed, as soon as the first

* See Sandifort, Thesaur, &c. 1768. Roterod. Art. Gummer. p. 505. Eph. Curios. Dec. 1, A. vi. vii. Obs. 20, 75, 76, 89, 125, 130, 192.

† See Reports of the Roy. Hum. Soc. for 1787-8-9, p. 77, as quoted by Cogan, obs. on apparent death, p. 106, Lond. 1815.

incision was made raised his hand; the heart of a Spanish nobleman, opened by Vesalius in order to discover his disease, was found beating.* Recovery from apparent death in consequence of fever and nervous diseases, is more frequent than from cold and suffocation. Frequently, injury done to the body in taking it out of the water, as also medical aid injudiciously applied, have destroyed life;† recoveries have taken place after considerable violence done to the body, simply by warmth and rest.‡ Sailors frequently fall from the tops of masts into the water, and the accident is generally fatal; recoveries, however, are stated under the most unpromising circumstances. A man fell from the foretopmast head of a ship, struck upon the foretop, and then upon the gunwale, falling, before he reached the water, not less than sixty feet: he was under water for eight minutes, and twenty more elapsed before any means of resuscitation was employed: the scalp was lacerated extensively, and he was otherwise bruis-

* See Reports of the Roy. Hum Soc. for 1787-8-9, p. 77, as quoted by Cogan, obs. on apparent death, p. 106, Lond. 1815.

† Cogan. Mem. of the Soc. Instit. at Amsterdam.

‡ Sand. Thes. Art. Gummer. 1768, &c.; also Reaumur nouvelle bigar, tom. x. quoted by Gummer.

ed, yet he recovered perfectly.* The temperature of the water also influences the probability of resuscitation;† it is stated, by Evers, that persons recover sooner after submersion in cold, than in warm water. M. Bucquet observes that irritable persons are most easily suffocated, and that they suffered less.‡ Experiments on the recovery of animals have not been so successful as those on the human body. Gummer found that young foxes and dogs rarely recovered by the use of heat and stimulants, after submersion for more than three minutes; and Kite seldom after eight, ten, and twelve minutes. The celebrated Bichat never succeeded in resuscitating animals, though his experiments were numerous.§ Habit has great influence in preventing death from submersion; persons accustomed to remain long under water, have continued for thirty and forty-five minutes beneath the surface, without injury.‖ Priestly observed the same facts with regard to the

* See Trans. of the Roy. Hum. Soc. from 1774 to 1784, p. 45-8, as quoted by Currie, p. 109.

† Ibid, p. 513, and Oswald on the phenom. &c.

‡ See Hist. de la Soc. Roy. de Medicine.

§ Kite's essay on the submersion of animals, p. 122, Lond 1795, and Sandifort Thesaur. Art. Gummer.

‖ Ibid, p. 507.

breathing of mephitic air ;* an impure atmosphere produced death in animals, which had lived in pure air, more speedily than in those to which habit had rendered its noxious qualities familiar.

Recovery in animals is also extremely irregular in its circumstances; in my experience, they resuscitated spontaneously after one and a quarter, two, two and a half, three, and even four minutes immersion ;† exhibited symptoms of imperfect recovery after four and five minutes,‡ but always died after six minutes ; no appearances of life remained sometimes after a much shorter period, even after one and a half and two and a half minutes.§ The appearances observed on the recovery of animals, are gasping, irregular and convulsive breathing, with spasmodic motions of the abdomen ; froth coming out of the mouth, with expression of great pain during and after recovery.‖

The usual evidences of death are cessation of the pulse, and of respiration, which is known by the application of the flame of a taper to the nose ; or the condensation of the vapor of the breath upon the surface of a mirror held before the mouth and nose ; or by placing a cup of water on the

* Kite, Lond. 1788. † Expt. 4, 5, 6, 21.
‡ Exp. 7, 9, 28. § Exp. 1, 12. ‖ Exp. 4, 6.

lower part of the breast-bone, and observing the agitation produced on its surface by the motions of the chest. The presence of the usual signs of death are not infallible: the body may be rigid, cold, and livid; the face black, cadaverous, and swollen; the eyes glassy or clear,* flaccid, heavy, dull, and fixed, or prominent and bloodshot; the mouth covered with froth; the pupils dilated; the jaws and extremities rigid, and inflexible, and the body pervaded with universal coldness, and yet recovery may take place.†

Favourable anticipations have been taken from the natural complexion of the face; Portal records a case of death from fixed air, in which, the eyes and whole countenance had the appearance of health; the fluidity of the blood is also an uncertain indication, because it is produced by other causes, and as in drowned animals at least it is not universal,‡ its certainty as a test is rendered still more questionable. The flexible state of the joints

* Reports of the Lond. Hum. Soc. vol. i. p. 87.

† See Kite, Lond. p. 94. Ibid, p. 15, for the case of a child which was smothered in a bed and restored to life notwithstanding the face was black and swollen. See the same work from 1774 to 1784, p. 87, for a case of recovery, in which the pupils were dilated and the eyes had lost their lustre, as quoted by Currie, p. 107.

‡ See Exp. 11, 15, 27, 31, 14, 27, 46.

is insufficient; the relaxation of the sphincter is not absolute; in the cat, it seldom if ever takes place.* Even signs of putrefaction are not certain indications of death; lobsters often have a putrefactive smell, when alive; Huxham mentions, that the texture of the body is sometimes loose in scurvy, and emits a horrible stench some time before death; in the last stage of yellow fever the perspiration has a cadaverous odour, for hours before life has ceased: Morton records a case of disease, in which the surgeon fainted from the smell of the blood, in performing the operation of venesection. Abscesses are sometimes attended with putrid discharges: Van Swieten mentions a case of long retention of urine, which on evacuation, was so noxious, as to produce a peripneumony in the attending surgeon. Persons have been frequently resuscitated when life has been suspended after typhus fever, a disease, in which symptoms of putrefaction may take place, and notwithstanding the patient recover. It may, however, be only confined to the secretions, and should from the facts above stated at least render our prognosis from this sign with regard to the issue of the case doubtful, and encourage proper endeavours to secure recovery. If putrefaction should be the result

* Exp. 8, 10, 11, &c.

of general causes, it is evident the issue must be fatal. The irritability of the iris is considered by Oswald, as the best test of remaining life,* also the sensibility of the internal membrane of the trachea, and the want of contractility of the muscles of the glottis, evinced by the presence of water in the lungs; an effect which, in all probability, never takes place till after complete death.†

Electricity has been proposed as a stimulus, to discover the remains of life;‡ and as according to Kite the irritability has continued 23 hours and 40 minutes after death, in the right auricle of the heart, its application may be useful.§

The appearances observed on the examination of bodies after death from submersion are various.

The external surface of the brain has been found to be darker than usual; the vessels are described by Goodwyn,‖ as being turgid without extravasation; by Oswald and Kite, extremely full of black blood,¶ and never moderately distended; a circumstance, which might be inferred from the

* Oswald on the phen. of suspd. animal life, p. 63. Philad. 1802.

† See Kite, p. 113. ‡ See Kite, Lond. 1795. p. 113.

§ Ibid. p. 114. Note.

‖ Goodwyn on the connection of life, &c. London, 1788.

¶ Oswald on the phen. of suspd. animal life, p. 23, Philada. 1802.

swelling and livid colour of the face, and the stoppage of blood in the right ventricle of the heart.

Kite, in other cases, found the vessels of the brain in several instances free from turgidity, in others rather empty. The time, which elapsed before examination, might have produced this difference; a conclusion, which the following observation would seem to confirm: the right auricle of the heart, and of course the superior cava, and its venous terminations, in a man who had been hanged, was found turgid by Harvey, on opening him before his face had lost its redness; on the next day, its turgidity had entirely disappeared.* In two dogs, which were drowned for dissection, De Haen found the brain distended with blood; in four others, this appearance was not seen.† In my experiments, the veins and vessels of the brain have been found sometimes pale and empty, at others, turgid.‡

The lungs contain generally a frothy liquid,§

* Kite in the recovery of the apparently dead, p. 31, Lond. 1778; and Expts. 57, 58, 59, in which a contrary effect was observed.

† Kite's Essay, 1788, quoting De Haen's Rat. Medend. continuat.

‡ Expts. 2, 7, 8, 10, 11.

§ Goodwyn on the connection, &c. London, 1788.

and are much collapsed, enclosing some air,* and after a long submersion are filled with water; the pulmonary veins and arteries are full of black blood. According to Oswald, the lungs in proportion to the size of the animal contain from one to fifty cubic inches of air: Kite found them in a complete state of expiration.† Coleman found in one experiment, the lungs to contain half a drachm of air; when distended, 16 drachms; sometimes scarcely a particle was collected; in this case Goodwyn supposes the lungs were emptied by the pressure of the atmosphere, and Coleman, that expiration is continued, till all the air is expelled.

Kite and Goodwyn found‡ no water in the lungs, when drowned in a coloured liquid, resulting, no doubt, from the irritability of the glottis. It is sufficient to state that there is generally little fluid of any kind found in the lungs till the glottis is relaxed by death, when they become full of water.§ When the animal breathes after emersion, the lungs are redder and contain some air;

* Coleman dissert. on suspd. respiration, &c. p. 82, Lond. 1791, and also p. 99.

† Kite, Lond. 1788, also Gummer. See Sandifort, thesaur. de mort. Submersor.

‡ Kite's Essay, 1788, London.

§ Kite's Essay, 1788, Lond. quoting De Haen, rat. med. continuat. See Haller quoted by Gummer in Sandifort. thesaur.

the thorax is more distended, and the veins near the heart are sometimes less full of blood: the trachea sometimes contains froth or water.*

Coleman found the two venæ cavæ, the right sinus venosus, auricle, and ventricle, and pulmonary artery loaded with blood;† the right auricle, ventricle, the left sinus venosus, and left ventricle are filled, and the left ventricle only half filled with black blood, according to Goodwyn; Oswald found the left sinus venosus and auricle only half full, whilst the trunks and smaller branches of the arteries, proceeding from the left ventricle, contained a quantity of black blood. Coleman found the quantity of blood in the right ventricle, compared to that in the left, in the proportion of twelve to seven, when examined immediately after death by tying up the two cavæ, aorta, and pulmonary artery; whilst the proportion of the right to the left was two to one, after the action of the heart had ceased. These proportions, however, sometimes varied; in some cases they were as seven to four, five to two, and twelve to seven; the medium ratio was one and six-eighths.

According to my observation, the heart and the

* Expt. 2, 7, 10, 11, 16.

† Coleman a Dissert. &c. p. 82, Lond. 1791. Kite's Essays, p. 210, et seq. also London, 1795.

blood-vessels, generally, with some slight variations, presented the following appearances: the veins of the neck, venæ cavæ, and axillary veins, the right auricle and ventricle, full of black blood;* the pulmonary artery containing some; the pulmonary veins distended, the left auricle and ventricle nearly empty, but in some cases moderately full, and the aorta containing very little blood.

When the resuscitation is partial the two sides of the heart are more equally distended, and the venæ cavæ less filled with blood from the effect of the circulation being longer continued.†

The stomach was found, by Coleman, to contain, generally, a little water;‡ Haller says, often none; the intestines never contain any water.§ De Haen, in thirteen experiments, found no water in the stomach, with which those of Kite entirely agree.‖

In some few instances I have found some water in this organ.¶ The peristaltic motion, according to my observations, generally, and to those

* Expts. 1, 2, 3, 8, 10, 11, 14, 16, 41, 57, 58, 59, 36.

† Exp. 7. ‡ Coleman a Dissert. p. 82, London, 1791.

§ See Sandifort's Thesaur. art. Gummer. Ræderer, quoted by the same author.

‖ Kite's Essay, London, 1788. ¶ Expts. 34, 36.

of Coleman, never continues as long as the contractions of the heart.

The bladder is frequently much distended in death from asphyxia.* Davy also makes the same remark.† I have seen it in one instance.

The body generally becomes stiff in an hour after submersion, and in the cat, according to my observation, it never remains permanently flexible.‡

On opening drowned animals immediately after death from submersion, the heart is found pulsating; and, according to Berger, it continues for two, three, or more hours after exposure to the atmosphere, and when it was not exposed it soon ceased to pulsate, reviving on the readmission of the air.§

In nitrous air it ceased to beat in an hour; in hydrogen in forty-five minutes; in carbonic acid in thirty-five minutes. A cat drowned at the same time, and laid in the water for the same period, exhibited contractions of the heart on opening the thorax, and exposure to the air continued its pulsations for seven hours, its colour becoming

* Portal quoted by Bichat on life and death, Phil. Ed. 1809, p. 231.

† See Davy on nit. oxide. ‡ Exp. 2, 3, 10, 11.

§ See Jackson's Essay on Suspend. Animat. p. 82, Phil. 1808.

scarlet and the auricles beating more frequently and much more strongly.

The irritability of the different sides of the heart is various; according to Oswald it remained an equal length of time in both:* in some instances the heart was found wholly destitute of irritability and insensible to the stimulus of galvanism: submersion in carbonic acid gas, in some cases, exhausted that quality, and, according to Coleman, it continued for twenty-four hours after respiration had ceased.

In no instance have I observed it to contract as long as twelve hours after death. Its motions are certainly increased by exposure to the air, on dividing the pericardium,† which renders it also more sensible to the stimulus of electricity. I have observed it to contract after clots had formed in its cavities;‡ the puncture of the cava and the pulmonary artery renews its contractions after they have ceased,§ and generally increases them.

The muscles lose their irritability sooner than the intestines and the heart.

The blood is rendered black by submersion,

* See Oswald on the phen. of Suspend Life, Phil. 1802.
† Exps. 9, 46, 51, 52.
‡ Exp. 33, 40.
§ Exp. 13, 16, 17, 23.

and those animals which are drowned in water of a high temperature, have it equally dark coloured in the arteries and veins;* according to the observations of Coleman, the blood of animals, drowned in water at 98°, is of a higher colour than that of the veins; and, contrary to the observation of Hunter,† I have found it sometimes coagulated.‡ The surface of the heart and lungs appear to have the power of coagulating the blood effused upon them.§

The blood-vessels, according to the observation of Phillips, communicate to the blood an irregular motion, even after the parts have become cold, and for seventy-five minutes after the heart was removed in one instance; he supposes‖ that it will continue for several hours after death; a fact which demonstrates the necessity of continuing our efforts to resuscitate the drowned persons longer than is generally practised.

It was thought proper to examine the state of the temperature in animals after submersion, to determine exactly the progress of its decline and its share in the production of death, particularly as this quality has been observed to exhibit some

* Oswald on the phen. &c. Phil. 1802.

† Hunter on the Blood, p. 22, Phil. Edit.

‡ Expt. 11, 15, 27, 31, 33, 46. § Expt. 63.

‖ Phillips' expl. enquiry, p. 209-10.

strange anomalies; thus an hybernating animal, kept in air of a very low temperature, and having that of its body reduced to nearly the same degree, after some time, had its temperature raised to the natural standard, as was supposed by Hunter, merely by the effort of the system, to heal a wound in the abdomen made for the purpose of introducing a thermometer. It was suspected some sustaining power like this might exist after death from submersion, and the following observations were made:

After submersion in water of 85° of Fahrenheit for five minutes, the air being of the same temperature, the surface cooled down to 92°: removed to the air, in ten minutes it fell to 90°, in fifteen minutes it fell to 89°, in thirty minutes to 88°, in fifty-two minutes the interior of the abdomen had fallen to 84°, when that of the room was 78°;—results produced principally by the suppression of the circulation, as the application of the tourniquet to an extremity of a living person produces the same depression of temperature.

In another instance the temperature of the exterior surface of the abdomen was 89° in air of 85° after two hours had elapsed, and in rather more than two hours and a quarter, the heat of the animal, below the abdominal muscles, was

92°.* In another instance, in twenty minutes after emersion, the surface of the abdomen was 88°, the air being 81°.† In a temperature of 73½°, when the head of the animal only was submersed and the body kept perfectly dry, the temperature of the exterior of the abdomen, in fifteen minutes, was 92°. In forty-five minutes‡ it remained at 92°; in one hundred and forty minutes it fell to 83°. In another experiment, in the same circumstances and temperature, the heat of the exterior of the abdomen fell to 90° in fifteen minutes; to 86° in forty-five minutes; and to 76° in one hundred and forty-five minutes;§ whilst in another animal, immersed in water of 60° cooling down to 42° by the addition of ice, in forty-five minutes, the temperature fell to 75° of Fahrenheit.‖

The strength and vigour of the animal, I have observed, certainly retards the reduction of the temperature, and water being a better conductor than air, favours the dissipation of the heat in proportion to their high or low degrees, as the above experiments show.

With regard to the effect of air of a higher temperature in submersed animals, it would appear that in one instance, when applied in the degree

* See Expts. 1, 2. † See Expt. 4.
‡ Expt. 10. § Exp. 11. ‖ Expt. 15.

of 160°, in twenty minutes it rose to 106°;* in another in the degree of 150°, in thirty-five minutes after immersion the body was 104°; in air of 120°, in thirty-three minutes it rose to 106°;† and of 111°, in not quite one-third of this time, the heat of the animal was 102°. So that, like the reduction of temperature, the power of the resistance to the reception of heat depends much upon the peculiar constitution of the animal. Other observations have been made; these are sufficient to illustrate this position, that animals in asphyxia have the power of resisting the communication of high degrees of heat, and prove that the powers of life, in this respect, continue for some time after their suspension.

* See Expt. 56. † See Expt. 24.

ON THE MODE

IN WHICH

THE CAUSES OF ASPHYXIA OPERATE.

Platerus in 1564, Borelli in 1680, Walschmiot, Littrius, and Becker in 1704, attributed asphyxia to defect of air: Dethardingius in 1714 believed that death proceeded from the expansion of the lungs; Senac, Leprottus, Winslow, Kaau, Boerhaave, supposed it to be owing to defect of air and to apoplexy: Louis to the stoppage of the circulation by pressure on the surface; Ræderer to infarction of the lungs; Evers to the suppression of the motion of the heart, produced by the superior weight and coldness of the water; and Villiers to cold, suffocation, and apoplexy. Haller and Engleman believed that death was owing to the loss of the elasticity of the air and the curved state of the vessels, and the consequent stop-

page of the circulation by the exhaustion and collapse of the lungs.*

The opinions, with regard to the causes of death from submersion, may be referred to cold, to loss of circulation, to apoplexy, and to defect of air: the reasons which support these opinions are as follows:

1. Cold.—This cause does not produce death from submersion, for animals die sooner when drowned in warm, than in cold water;† besides exposure for a long time to water of a low temperature does not produce death, provided respiration be continued, and frequently after submersion death is complete, though the temperature does not, for a considerable time, decline to a degree inconsistent with life;‡ yet in these cases spontaneous recovery did not take place, which should have happened had want of heat been the cause of death: cold, no doubt, assists, because it debilitates the body when long applied, in a high or low degree.

2. Loss of circulation.—The pulse ceases, according to Oswald, between two and three minutes after submersion, and it continues, with the

* Sandifort Thesaurus Dissert. Jac. Gummer. de causa mort. submers. 1768, Roterodam.

† See Art. Gummer. in Sandifort Thesaur. 1768, Roterod.

‡ Expt. 10, 11.

other functions, an indefinite length of time when the breathing is continued; though the body be immersed in water, it is evident the stoppage of the circulation is not the cause of drowning, but an effect.

3. Apoplexy.—From the fulness and slowness of the pulse observed in about one minute after submersion; from the lividness of the gums and face; also from the hemorrhagies from the nose and ears of divers, the sense of fulness of the head when the same air is breathed for a long time, or the breath is entirely suspended, it is evident that appearances resembling apoplexy must take place in submersion, and dissection gives some support to this position, for the vessels of the brain are sometimes found turgid; but as there is no extravasation, and as frequently there is no turgidity in the vessels, on the contrary they are perfectly empty, and as death generally takes place in four minutes, and sometimes in two or three, and even in one minute after submersion, it is evident that apoplexy cannot be the cause, for this disease, in its natural form, sometimes continues for days, and generally for hours, with a full and bounding pulse, great distention of the vessels of the head, and even extravasation without producing death: besides the turgidity of the vessels sometimes seen after death from submersion is not owing entirely to in-

creased action of the arteries as in apoplexy, but more to a remora of the circulation in the veins, caused by the fulness of the right auricle and the compressed state of the thorax and lungs, produced by the weight of the atmosphere, and the water, and the contraction of the arterial system after death, and in proof of this circumstance, the veins of the axilla are found equally distended with those of the brain, from the influence of these causes.* The experiments of Coleman, however, put it beyond all doubt. The vessels of the brain were exposed immediately after death from submersion for four minutes, and they were found less distended than usual. The carotids of a dog were secured in order to prevent apoplexy; in half an hour he was submersed; life ceased in four minutes, and the vessels of the brain were found less distended than in ordinary death; of course apoplexy cannot be the cause.†

4. Defect of Air, or Suffocation.—As we know that respiration is essential to life, and that submersion may be safely continued for a long time, if respiration be not suspended, and as death is the immediate consequence of the suppression of this function, the conclusion is certain, that suffocation is the cause:

* Expt. 32. † Coleman a Dissert. &c. Lond. 1791.

Accordingly we now proceed to detail the circumstances, on which perfect respiration depends, in order to expose the subject in all its lights, and then deduce the most approved mode of cure.

Of the function of respiration as the place of origin of Suspended Animation.

The phenomena of respiration are, mechanical, chemical and vital. After the air is inspired, the lungs, consisting of a vesicular structure, absorb the oxygen and leave the azote, mixed with some carbonic acid, formed during the process.

Mechanical Phænomena. As a general position, the duration of the scarlet colour formed during respiration depends upon the quantity of air, contained in the lungs, diminishing in intensity as the oxygen disappears; the agitation produced by these organs also prolongs it;* yet, if the lungs be violently distended and the air already in them does not escape, oxygenation is retarded; even if the residuum in the lungs be exhausted, and fresh air be injected, the scarlet co-

* Bichat physio. research. Phil. 1809, p. 213.

lour is not so soon produced, as by natural respiration.* It is then important to ascertain exactly the number of natural respirations, in order to produce the greatest possible effect in resuscitation; particularly, as inflation produces the temperature, and retards its decline, as well as oxygenates the blood.† According to Kite, the lungs receive three hundred cubic inches of air, and the chest in every minute makes about ten respirations; to Davy twenty-seven or twenty-eight.

When the body is bent in a sitting posture, near a table, and the thorax expanded itself with some difficulty, thirteen respirations were made in a minute, according to my observations; when the back leaned against a chair, and the thorax was free, nine respirations were performed. Respiration is affected by the state of the mind, even by attention to the experiment.

In the morning after breakfast two respirations in a minute were found sufficient for the space of one minute; during the second three were necessary. When the experiment was repeated in the evening two respirations in the minute were sufficient for the support of life, and could be con-

* Bichat physio. research. Phil. 1809, p. 217.

† Philip's enq. p. 215, Phil. Edit. 1818.

tinued for three minutes; afterwards three were necessary, and even these produced, after some time, some slight fulness of the head. On repeating it I found that I could subsist with comfort on three respirations in a minute; the experiment lasted for twelve minutes, and there was no apparent diminution in the power of continuing them. A middle number of respirations between three and thirteen in a minute, increasing according to circumstances, is, then, about the natural standard.

The degree of pressure occasioned by inflation also causes a difference between natural and artificial respiration.* When air is forced into the lungs with great violence, emphysema is the result in the breast and neck; and when the force is only moderate, the air passes, in a separate state, into the arteries,† an effect which has taken place, even in colic, from the pressure produced by the spasms; also sometimes in greatly hurried respiration.‡

In my experiments, the air forced into the lungs with some violence by the bellows, rose on the surface of the exposed lungs, like bubbles oozing

* Philip's enquiry, Phil. Ed.

† Bichat phys. researches, p. 249, 247.

‡ See Morgagni and Pechlin, quoted by Bichat phy. researches, p. 249.

from mud, and passed to the surface of the pericardium and into the cavity of the abdomen near and behind the kidneys.* On the contrary, the effect of artificial respiration, when too little or rarefied air is injected into the lungs, equally retards oxygenation.

After the air is admitted into the lungs, its oxygenous portion unites with the blood, produces the scarlet colour, and forms carbonic acid, which is discharged by the mechanical actions of this viscus.

The oxygen of the atmosphere appears to be equally necessary to the vegetable and the animal world: Davy found that plants looked better, but for a shorter time in oxygen than in atmospheric air:† bees, snails, (helix pomatia),‡ slugs, (limax flavus),§ destroyed the oxygen completely: Spallanzani found that the helix vivipara, an aquatic animal, ceased to change the air at the temperature of freezing: near the bottom, they consumed only half the air, which they did when allowed to breathe at the surface; and when they breathed

* See Expt. 41, 42.

† Davy on nit. oxide. Hub. Mem sur la Germin. &c. and Sennebier. See Ellis, an enq. into the changes, &c. Edin. 1807.

‡ Vauquelin, quoted by the same.

§ Spallan. quoted by the same, p. 73, 74, 75.

the air alone, the oxygen was destroyed without the azote being the least diminished;* some amphibious animals, as the sea tortoise, will live in the hold of a vessel or in the bottom of a hogshead for many months, though the air be impure. Birds die before half the oxygen is consumed: a mouse and a guinea pig expired when about three fourths of the gas had disappeared, though the carbonic acid was withdrawn.† Spallanzani observed that birds and quadrupeds do not consume more than $\frac{19}{100}$ parts of the oxygen, and sometimes only 17 or $16\frac{15}{100}$ parts, and then die, though the fixed air be removed, proving clearly that air frequently renewed is absolutely necessary for the existence of these animals. It would then appear that as we ascend the series of animation, the higher orders require air better ventilated than the lower.

Atmospheric air appears to be necessary to all species and orders of living beings, for it has been satisfactorily proved that oxygen, when pure, will produce convulsions, debility, and death, though the carbonic acid be removed by lime water.‡ It causes a sensation of warmth in the lungs, great excitement, an increase of strength, fulness and

* Ellis, p. 76. † Ibid.

‡ Higgins' Phil. Expts. Lond. 1795, p. 146 et seq.

frequency of the pulse, rising, in one instance, to ninety, in another to one hundred and twenty beats in a minute, when sixty-four was the natural number in the same period. In the experiments of Davy, oxygen produced oppressed respiration, though little of the oxygen had been consumed.* He also found that man and the mouse consume less oxygen, and produce less carbonic acid, when they breathe in pure oxygen, than in common air.† There can be no doubt, then, that the dilution of the atmosphere by azote renders it more favourable to the support of animal life, and that pure oxygen is improper for resuscitation.

Habit, however, has a great effect on the power of animals to breathe air already tainted by respiration; Priestley found that those animals which breathe pure air will die sooner in impure air than those which have been accustomed to it.‡

Natural peculiarity of constitution has also an influence; certain fishes die immediately on being exposed to the atmosphere; others live many hours: all the organs of the body have various degrees of strength in different individuals; one person recovers from drowning, though he has been

* Davy on nit. oxide. † Ibid, p. 442-4.

‡ Kite, Lond. 1788.

submersed for half an hour, simply by the effect of rest and the sun; another dies irrecoverably after immersion but for one minute. Such is the effect of constitution.

Other circumstances also have an agency; and, in general, any cause which debilitates or strengthens the system, or changes the qualities of the atmosphere, produces difficulty or freedom of breathing.

In this country, during the prevalence of cold and dry winds from the north and west, the tone of the system is increased and the lungs play with ease; on the contrary, when the system is bathed in vapour by the eastern winds, which blow over the ocean, and particularly in warm seasons, the system is weakened and the breathing is oppressed. The same effect is produced by respiring frequently from a vessel of small capacity,* by the impurity of the atmosphere of crowded rooms, and of museums; by the debility of the system produced by fear, horror, fatigue, digestion, fever, dropsy, gout, consumption, or other chronic diseases.

It would appear, then, that the lungs should perform their functions properly, the air must consist of the proper proportions of oxygen and

* Prof. Pfaff quoted by Ellis in an enquiry, O. Edin. 1807.

azote, have a due and not excessive degree of moisture, and be freed from noxious vapours by ventilation.

After the air is admitted into the lungs it unites with the blood; Priestley and Cigna found that venous blood becomes florid at its surface, when exposed to the atmosphere, though covered and defended by a thick stratum of serum.* The experiments of Hooke prove that it combined with the blood after the natural and mechanical motions of the thorax were suspended by opening it; and of Brodie, that oxygen was absorbed and carbonic acid formed in the same condition of the lungs.†

It would, then, appear from the most demonstrative and conclusive evidence, that after apparent death respiration may be continued, and also that its peculiar changes on the blood may be produced.

After explaining the causes which affect the strength and perfection of the organs of respiration, we proceed to explain the mode of operation of those causes which entirely suppress it, and produce asphyxia.

It was stated, in the commencement of this me-

* Davy on Nit. Oxide, p. 445.

† See Croonian Lecture, 1810.

moir, that the various species of asphyxia were essentially the same; we shall now attempt to prove this position by showing the effects of the noxious gases, suspension, &c., and thus prepare for the discussion of modes of cure, which shall comprehend them all.

Oxygen, when pure, is unfavourable to animal life, and produces convulsions and death, as in submersion, though not so speedily;* nitrous oxide, according to Davy,† destroys warm-blooded animals much sooner than oxygen, but not so soon as the non-respirable gases; the larger and the old live longer in it than small and young animals: vegetables also die in it;‡ a butterfly died in half a minute, and a fly in the same time;§ fishes and lizards, (as happens in water freed from its air,) do not die so speedily in this gas. Animals die in nitrous gas in the space of from one to five minutes, which corresponds, pretty exactly, with the effects of submersion,‖ and the appearances after death resembled those from the latter cause,¶ with these differences, that the blood in the left side of the heart and the aorta was more purple, and the irritability disappeared sooner,

* See p. 53. † Davy on Nitrous Oxide, p. 366.
‡ Ibid, p. 563. § Ibid, p. 371.
‖ Ibid, p. 339—40. ¶ Ibid, p. 346.

than when the animal is killed by a blow.* This sudden loss of irritability often appears after drowning, and the purple spots in the lungs, mentioned by Davy, sometimes are seen, particularly if the animal has breathed during submersion. Equal parts of nitrous oxide and hydrogen killed in the same manner, and with the same appearances after death.† Three parts of hydrogen and one of nitrous oxide destroyed a mouse in a minute. Pure hydrogen could not be respired more than three quarters of a minute; giddiness, muscular debility, a feeble pulse and a sense of suffocation were the result.‡ The same symptoms occur in submersion in about the same period. Azote, in union with a small proportion of carbonic acid, produce the same effects: nitrous gas, sulphurated hydrogen, and hydro-carbonated gases also destroy in the same period, with this exception, that it has been believed that the two former are absorbed, and the latter produces in the blood a red colour; in other respects, the essential symptoms, the state of the lungs, heart, and brain are entirely the same as in submersion.

Carbonic acid, according to Davy, is irrespira-

* Davy on Nitrous Oxide, p. 348. See a Diss. on Nit. Oxide, by W. P. C. Barton, 1808, p. 76.

† Davy on Nitrous Oxide, p. 358. ‡ Ibid, p. 466.

ble from the closure of the glottis; another circumstance, in which it resembles water in its effects; the limbs in death from the former do not generally grow stiff: this sometimes happens in death from submersion.

It is stated, by Currie, that Dr. Black observed that birds immersed in carbonic acid gas were not so speedily killed when their nostrils were stopped with suet as when they were left open, proving that this gas operates upon the nervous system in producing death:* these results are confirmed by Dr. Rousseau, an ingenious physician of this city, who states, that when the nostrils are closed the inhalation of carbonic acid is not deleterious. It is most probable that it acts both by excluding oxygen from the irritation of the glottis, which fixed air always produces, and also that it has a narcotic effect on the olfactory nerves. In Russia it is believed, by Dr. Guthrie, when a thaw succeeds a frost of long duration, that the thin plate of ice which forms upon the windows, on thawing, gives out a principle which is supposed to be the carbonic acid discharged by respiration, and which produces all the deleterious ef-

* See Black's lectures on chemistry, edited by Professor Robison, vol. ii. p. 87, quoted by Currie, p. 129.

fects of this gas.* This subject, according to this gentleman, has been rigorously examined, and no other source can be discovered for this noxious vapour, as the stoves are found to be perfectly tight.

From these facts it appears that the non-respirable gases, as far as they have been examined, produced essentially the same phænomena, when applied to the lungs, as water in submersion, and also in the same period. Convulsions frequently occur during immersion in these airs, as also in water, and the same irregular affections, pains in the head, drowsiness and giddiness for some time after recovery.

Suspension by the cord kills also by the exclusion of respirable air from the lungs. Munro hung a dog, in whose trachea an opening was made below the place of pressure, and the animal lived: in three quarters of an hour the rope was placed below the opening in the trachea so as to prevent respiration, and the animal soon died. The jugulars and the carotids have been tied and life has been prolonged for weeks, proving that death from strangulation is not produced by pres-

* See Phil. Transact. Lond. vol. lxix. p. 325, for 1779, as quoted by Currie, p. 130.

sure on the blood-vessels:* nor is compression of the nerves of the neck the cause; otherwise in the experiment of Munro above related, the animal would have died immediately and before the pressure was made below the hole in the trachea: The nerves, which are liable to be affected by suspension, are the great sympathetic and the par vagum; a ligature on these nerves does not destroy life for some time;† whereas, in suspension, death is the result in a few minutes. Pressure on the spinal marrow cannot take place without a fracture of the vertebræ, which does not always occur; in animals, the subject of these experiments, never; yet death, in about the same period as in submersion, uniformly is the result. The symptoms felt on suspension, and described by those who have recovered, are similar to those experienced after submersion,‡ and the same appearances observed after death, in both varieties of this disease.§

* See Kite on, &c. 1788, Lond. p. 198.

† See Bichat phy. res. p. 259, Phil. Edit.

‡ See the Repts. of the Hum. Soc. for 1785-6, p. 138.

§ See Coleman.

From what has been already stated, the operation of the causes of death in this disease, which arise from the mechanical and chemical functions of the lungs, can now be understood. The division of the eighth pair and of the upper parts of the spinal marrow, supplying the glottis, the muscles of inspiration, and the diaphragm, destroys the vital powers of respiration: By wounds in the chest; by a strong compression of the abdomen and thorax, and by a great accumulation of fluid in the cavity of the chest; the mechanical functions of the lungs are suspended. The operation of rarefied air, of submersion, of noxious gases, and a closure of the trachea by natural or artificial means, prevent the chemical changes of the lungs and thus produce the disease.

Those which arise from causes affecting the vital phænomena of the body remain. Of these, the first is cold. In order to explain the operation of this agent, it will be necessary to examine the general relations of animal temperature, without entering into a discussion, with regard to its origin, which would exceed the limits of this essay.

The heat of the animal is intimately connected with life, and is a necessary agent in supporting it. From some experiments performed and carefully repeated, I have found the temperature of animals

to decline in proportion to the distance from the heart: its power of preservation also is less considerable in the more distant than in the central parts of the body: the feet first lose their heat in dying, and on exposure to intense cold: the power of generating this fluid also depends much upon the strength of the system: those who are convalescent are more susceptible of changes of temperature, and are more liable to cold feet and chills over the whole body; the phlegmatic and the dropsical are more sensible to cold in winter than the sanguine, and this in the parts most distant from the heart. Palsy also takes away the power of preserving the temperature,* and it is certain that the debilitating passions of the mind lessen this power, proving that the state of the brain and the system generally contribute to this effect: the nerves and the blood-vessels also are intimately concerned in this function: a ligature on either of these structures lowers the temperature and affects the powers of preservation in the parts on which they are distributed. It is, therefore, a quality, which depends upon the integrity of every part of the body, and is more or less affected by every thing, which impairs or strengthens it: Thus a wound increases the heat of the whole system, if

* See Earle's Expts.

considerable enough to excite re-action; if in a vital organ, it lessens the temperature, if re-action does not follow. The effect of wine strengthens the system for a time, increases its temperature, and debility is the consequence, and a greater sensibility to cold.

The most general law, which this quality presents, is that its power of preservation, and of course its actual degree, diminish in proportion to the distance from the heart, and that they both increase with the general strength of the system when in health, never rising, however, beyond a certain temperature, which varies according to the class of the animal.

The symptoms of apparent death from cold are, coldness, numbness of the extremities, loss of the power of motion, and irresistible propensity to sleep, ending in complete asphyxia, and if it should continue, in death: the common appearances of which are, insensibility, inflexibility of the limbs, with the jaws fixed, the teeth clenched, and froth issuing from the mouth.*

The symptoms of recovery observed in the marmot are deep sighs, with broken and inarticulate sounds; the limbs become less rigid, the animal stretches out his legs and fetches another still

* See Struves' Pract. Essay, p. 52, Alban. 1803.

deeper sigh, opens his eyes, and at length recovers.

It is singular, though the temperature be equal to that of freezing, the marmot never becomes torpid, provided he be kept in the open air instead of a close place.*

This state may be hastened by this circumstance, as the carbonic acid produced during breathing would undoubtedly cause asphyxia without the assistance of cold.

With regard to the actual power of bearing cold possessed by the living system, it appears, from the experiments of Hunter, that the temperature of the mouth may be reduced 20° by the application of cold, and the animal sustains no serious injury, and that of the urethra 40°. Dead matter loses and is increased in temperature more rapidly than living. The urethra immersed in water, heated to 113° for two minutes, rose to the temperature of 100½. Exposed to water heated to 118° for some time, it rose to 102¼, but no higher.†

In my experiments on animals which had been submersed in air of a high temperature, it appear-

* See Buffon's Nat. History of Animals, quoted by A. Fothergill in a new enquiry, &c. Ed. 1798.

† See Hunter's Obser. on certain parts of the Anim. Œcon.

ed that they received heat more slowly than in those of Mr. Hunter. Immersed in air of 150° of Fahrenheit for thirty-five minutes,* the body was 104°. In air of 120°,† in thirty-three minutes, it rose to 106°, and in air of 111°,‡ in not quite one-third of this time, the heat of the animal was 102°. So that the power of resistance of the animal to the reception of heat, even during asphyxia, produced by submersion, was considerable. Animals placed in air colder than their natural temperature lost their heat generally in proportion to the degree of depression of the medium.

In a temperature of 60°, in about forty minutes it fell to 73°,§ and proportionally less according to the higher degree of the air to which they were exposed, and varying, in some instances, from other causes, as strength of constitution and abstinence from food: this last result coincides with the experiments of Mr. Hunter.‖ The male cat also preserves its heat after submersion longer than the female.

The operation of *cold* in producing death is easily traced in the symptoms already detailed: the sleepiness and comatose disposition, which

* Expt. 18. † Expt. 24.
‡ Expt. 20. § Expt. 44.
‖ See Observ. on cert. parts of, &c. Lond. 1792.

occurs on its first application, prove the weakness of the brain; the numbness, insensibility, and loss of voluntary motion show that the functions of the nerves and muscles are also debilitated, and at length entirely suspended. The blood-vessels also lose their power and contribute to this effect. From the experiments of Spallanzani the oxygenation of the blood, which takes place even after death, is, by a low temperature, completely prevented.* Cold then acts, in inducing death, on the general powers of life; the remains of the respired air are not ejected by the loss of power in the muscles of expiration, and the oxygen present in the lungs is not assimilated from the want of attraction in the blood; thus, then, the animal dies from the suspension of the mechanical and the chemical functions, produced by the general decrease of the vital powers.

Hunger also operates by inducing debility of the powers of life. The muscles of inspiration cease to perform their functions, asphyxia takes place, and, from the extreme debility, soon terminates in death.

The various species of fever produce this final change in the same manner.

All these causes may operate either slowly or

* See Ellis, p. 76, and p. 34 of this Essay.

rapidly. The division of the eighth pair of nerves may be partial, or combined with that of the spinal marrow above the origin of the phrenic nerves; the quantity of water injected into the thorax may be greater or less; as also the pressure of tumors on the trachea; asphyxia accordingly will be more or less sudden. The decline of irritability after death, it has been ascertained, will be proportioned to the duration and violence of the pain which has exhausted the animal previously, and of course the probability of resuscitation* more or less certain.

We have now attempted to prove that the various species of asphyxia resemble each other in their origin from the lungs, and the formation of blood unfit for the purposes of life. On reviewing the causes which produce this disease we find that they are allied by close affinities, and that they often unite in its formation. The rarefaction of the air, want of food, and cold in its higher regions, all frequently concur in producing death. Heat also sometimes combines with rarefaction of the air and want of food, as in the noxious winds of the deserts of Africa, and frequently acts alone, as in the humming-bird, which is said to

* See Bichat's Phys. Researches.

become torpid during the summer in South America.

It now remains to ascertain exactly what changes these various causes effect in the interior of the body by which death is produced.

When the trachea is closed, the blood, in general, begins to change in thirty seconds; in one minute its colour is darkened, and it becomes perfectly like venous blood in one minute and a half, sooner or later, according as the lungs are more or less free fom air. This dark blood is the principal cause of death; other circumstances, however, conspire.

1st. Mechanical causes. The compressed state of the lungs has been considered, by some authors, as preventing the circulation, but experiment does not confirm this supposition.* Bichat and Coleman found, contrary to the opinions of Haller and Cullen, that the circulation went on equally well when the lungs were entirely collapsed or distended; this fact may be true in cases where the heart possesses considerable power, as in those on which the experiments were made; but it is certain, that as during asphyxia, this organ is much exhausted, that the motion of the lungs must have considerable effect in accelerating the

* Bichat's Phys. Researches, p. 173-4, Phil. Edit.

blood, as it certainly would have, even in inanimate tubes. The effect they produce by compressing the contents of the abdomen, and thus forcing on the blood through the arteries and the veins into the right side of the heart, must be considerable.

Bichat observed that the quantity of blood was increased, on dividing the carotid, every time the motions of respiration were accelerated by pain, though the number of the pulsations of the heart was not increased; proving, clearly, that these motions produce a great effect upon the condition of the blood-vessels, and that, of course, their loss must be one of the chain of causes which produce death.

2nd. Chemical causes. According to Goodwyn the cause of death is the want of scarlet blood, the appropriate stimulus of the left auricle, confining the seat of the disease entirely to the heart. Bichat believes that it is the presence of black blood in the vessels of the heart and in all the organs of the body which produces the effect.

From my observations, I should conclude that the heart was debilitated in its action, first, from the effect of black blood in the lungs, lessening, by sympathy, the power of this organ; for its action is instantly renewed and invigorated by in-

flation, before the scarlet blood can reach the left auricle and ventricle.

2ndly. The transmission of the black blood into the coronary arteries, which takes away the power of its fibres; as it weakens and destroys the functions of the brain, the nerves, the voluntary muscles, in fact of most of the organs of the body through which it penetrates, as is proved by tying up the artery of a limb, and the injection of black blood into the carotids—the functions of the brain in the latter, and of the nerves and muscles in the former, being completely suspended; it is, therefore, very certain that the fibres and nerves of the heart are equally weakened by the contact of black blood. That it is not owing to the want of the stimulus of the red blood on the interior of the left auricle and ventricle as Goodwyn supposes, Coleman states that the case of the fœtus, whose heart moves from the stimulus of black blood, is sufficient proof. To this, it may be replied, the analogy is not sufficiently strict; for, in fœtal life, the organs possess properties in many respects different form those of the adult.

It bears asphyxia better than the adult, a quality which continues for some time after birth, showing that the power of the heart is more independent of the lungs in the fœtus than in the adult, an important difference, as these two organs are

primary in the production of asphyxia. It is incapable of supporting an independent temperature, requiring a degree equal to the mother in order to live, and many of its organs, the brain, the nerves, the senses, digestion and voluntary motion, are almost entirely at rest. It is, therefore, improper to make a comparison between them. Let us then recur to the facts in the adult system.

That the scarlet blood can act upon the left auricle and ventricle, by distention, is satisfactorily proved by the injection of black blood into these cavities, reproducing their motions after they have ceased;* that it operates by its qualities as arterial blood upon the left side of the heart, it is sufficient to state that it is its natural stimulus in the adult state. A contrary effect, however, is produced in the right ventricle, during asphyxia, from the distention of the stagnating blood which does not pass through the lungs; for when the venæ cavæ, or pulmonary artery, are punctured, the right auricle and ventricle resume their contractions, even after they have ceased.† This, however, would appear to be the case only when the distention is considerable, and only with regard to the right side of the heart, for in the left ventricle the

* Bichat's Phys. Researches, p. 179.

† See Expts. 9, 13, 16, 17, 22.

irritability is prolonged by tying the aorta and confining the blood in its cavity.* The distention of the right side of the heart is never excessive, as appears from gentle pressure with the finger, expelling its contents, and from the fact, that these cavities of the heart are filled merely by the contractility of the veins, which is always weak: in consequence, the valves between the auricle and ventricle, as also between the latter and the pulmonary artery, do not perform their functions completely; the blood, accordingly, in the contractions of the auricle and ventricle is never sent into the pulmonary artery, or in very small quantities, regurgitating into the ventricle, or passing between the auricle and ventricle, without even distending the pulmonary artery, so that the functions of this organ are weakened in every respect; in the right side by distention, and in the left by the want of it during suspended animation.

It would appear, then, that the interruption of respiration places all the parts in a state opposite to that of nature, and thus produces death. The cavæ and venous system generally are much distended; the right side of the heart so much so as to exhaust the little remains of irritability of this organ; the pulmonary artery and lungs contain but

* See Bichat's Phys. Researches.

little blood, a condition equally unnatural, as they are deprived both of the stimulus of distention and scarlet blood: the pulmonary veins are turgid and filled with stagnant blood, and the left auricle and ventricle are deprived of red blood, and are empty; conditions almost in every instance, the contrary of what happens in the living state, showing the great power of the lungs and its appropriate stimulus over the system, thus to overthrow and reverse the qualities of life in all the important organs; and leading to the conclusion that it is by re-establishing the natural state in each of these particulars, that resuscitation will, most probably, be effected.

Bichat has proved satisfactorily, that the brain dies by the contact of black blood, and that, of course, the suppression of respiration acts in this manner on this organ in asphyxia: mechanical distention, produced in the increased action of the heart, also appears to have some connection with this effect. When red blood was injected, by a syringe, into the arteries of the brain, the appearances of life were feeble, and death generally took place, a result which might have been expected from the rude imitation of the arterial action which this process presents. We can now explain satisfactorily the various phænomena of asphyxia; the anxiety first felt in the lungs prove the origin of

this affection to be in that viscus; the continual struggles till death takes place show the violence of the feeling; the black blood penetrates the heart and is sent with force to the brain, and, in the space of forty-five, sixty, or ninety seconds, the functions of this organ are entirely suspended, as far as regards external objects; a period, which corresponds pretty exactly with that of the formation of black blood, by the suspension of respiration, in the experiments of Bichat.

The pulse, during the loss of the scarlet colour of the blood, becomes fuller and slower, from the effect produced upon the brain, and gradually declines till it ceases altogether; as a proof of which, if the animal be permitted to breathe, these changes do not take place; the system then exhibits some distracted motions, which are the result of the remains of life in the different parts of the animal, displaying, however, the best directed efforts to replace it in its original state, by re-establishing respiration.

We proceed, in the following chapter, to assemble all the indications presented by this survey of the phænomena of asphyxia, to restore the animal to health.

ON THE

CURE OF ASPHYXIA.

First, from Submersion.

The body must be recovered from the water, stripped, dried, wrapt in warm blankets, and then conveyed, with as little agitation as possible, to the place of resuscitation. The old custom of rolling the patient upon a barrel, or upon the ground, of violently shaking, or carrying him over the shoulders of another person, with the head downward, have been deservedly omitted. Agitation of the extremities, it is certain, has an effect in exciting the heart, for by pulling the aorta, the axillary and carotid arteries, the heart being exposed to view, its motions were considerably increased* as long as any irritability remained; this remedy, however, promises little benefit till respiration is established, and the heart begins to

* Expts. 36, 54.

recover its power, and then, as in exercise, it may increase its motions; it should be confined to the upper extremities only, and applied by approaching the extended arm gently towards the head, and restoring it to the side, as by this means, the axillary artery will be best extended and relaxed. If long submersed, inversion of the body, for a few seconds, to discharge the water from the lungs, may be necessary: it should be done gently and with the greatest care. An instrument has been proposed for exhausting the water from the lungs; but the above expedient will be sufficient.

After being well dried with flannel, it should be laid upon a litter, a bed, or in a carriage with straw; the head gently raised, and the body placed in a supine posture: formerly, the patient was advised to be placed on one side, rather than upon the back, and occasionally upon the breech.* Kite recommends a posture in an angle of 20° previous to the use of any means of resuscitation; this position would have an unfavourable effect, as it would increase the pressure and the quantity of blood in the right auricle and ventricle, which, from observation, has a tendency to weaken their motions, and retard the passage of blood, by the

* Mem. of Vicentini in Cogan's translation of the Amsterdam Soc. Memoirs.

pulmonary artery, through the lungs. If the body be raised and the head depressed, the quantity of blood in the right side of the heart would be increased, in a greater degree, by the pressure of the column, extending from the feet to the heart, and therefore, this posture is equally improper. The horizontal, the medium between the two, appears to be preferable, as, then, when the heart begins to act, the blood passes into the head without the disadvantage of the resistance of gravity, as when the head is raised and the feet depressed, or the contrary; and without the additional disadvantage of the pressure of the column of blood on the veins, distending and weakening the motions of the right side of the heart.*

The place to which the body is to be removed is next to be chosen. From the debilitating effects produced by slight impregnations of the air with noxious vapours, with moisture during the prevalence of east, in Europe, and of west winds in America, it is evident that as few persons should be admitted as possible; six active and sensible men will be sufficient; the room should be well ventilated, and have an airy, northern, and dry exposure. These considerations are important; as in cities, and in situations near the water, where

* See page 30.

these accidents most frequently happen, all these disadvantages are most frequently combined, and the lives of many persons, whose constitutions are weak, may be lost from inattention to them.

With regard to the application of heat, various opinions are entertained. Submersion, for a few minutes, abstracts but little heat from the body. According to Goodwyn, the temperature may be raised to 100° of Fahrenheit, and then artificial respiration may be used. Coleman thinks the gradual application of heat is unnecessary, and that respiration may be commenced immediately. The temperature, according to Hunter, should be proportioned to the degree of life, and as heat produces greater excitement than cold, a sudden elevation may destroy the resuscitating animal.* He found that if an eel be exposed to a degree of cold sufficient to benumb it, till life is scarcely perceptible, and be retained in a temperature of about 40°, it will remain without change; but if the animal be placed in a temperature of 60° it will show strong signs of life, and die in a few minutes: birds are killed in the same manner: snails, leeches, earthworms, fishes, dormice were frozen and could not be recovered; the ears of rabbits, the tail of the tench, and the comb of the cock were frozen

* Kite, p. 88.

and restored more easily.* The gradual application of heat, however, has been tried, though not under circumstances sufficiently precise to determine with perfect accuracy the effect. An animal was drowned and reduced to a temperature three degrees below that of the atmosphere; it remained in the water, and electric shocks were passed through it, so as barely to excite a contraction in the muscles; the temperature was then raised three degrees every five minutes; the irritability diminished at every step, and before the body had acquired its natural temperature, it was entirely lost.† The principle of the application of heat has not yet been precisely ascertained.

On this subject I have made many observations, but, from the great variety in the duration of the irritability of the heart, sometimes ceasing after a few minutes, at others not for hours, in various temperatures, I can draw no positive conclusion from them, excepting with regard to the influence of temperatures above 98°; then the heat of the animal rises above the natural standard, and, of course, must prevent success. The temperature of 150° of Fahrenheit produced rigidity of the

* See Kite, Lond. quoting Hunter.

† Kite, Lond. 1795.

limbs in a short time, and, of course, rendered death certain.*

In one experiment, in air of 100° combined with inflation, the circulation was much improved, and the arteries contained more blood than usual.† In other and lower degrees, the effect was variable.‡ The opinion of Hunter is most safe on this difficult practical question; that is, that the application of heat should be proportioned to the degree of life, and that it should be gradual, a precaution indispensable when the temperature of the body has been much reduced: if the body should be nearly frozen, it may be necessary to immerse it in snow, or cold water, and then gradually increase it.

With regard to the mode, exposure before a warm fire; the application of cloths wrung out of warm water; immersion in warm grains from a brewery; or in warm water; sand; embers; or lees; or in a bed heated by the human body; or by a warming-pan; exposure to the sun; hot bricks, or hot bottles filled with water, rolled in cloths, and applied to the neck, armpits, back, knees, ankles, and soles of the feet, have been proposed. As

* See Expt. 18.

† See Expt. 43. Of course, the simple effect of heat could not be known, as it was combined with inflation.

‡ See 27, 29, 30, 31, 32, 33, 34, 36, 38, 40.

ardent spirits produce cold by evaporation, it is an improper application to the skin; a poultice, made by boiling ginger in hot alcohol, has been recommended to be applied to the feet: hot water in bottles would be more easily procured, and is equally efficacious. A machine has been invented by Dr. Harvey, of Manchester, for communicating heat to the body; it consists of a hollow tin apparatus, in which the person is laid, and filled with warm water, which is renewed as often as may be necessary.* This plan of heating the body by water is certainly not so desirable as by air, sand, or placing the body before a fire; for water has a debilitating effect independent of the heat.

When the body is properly prepared for commencing respiration, the lungs must be inflated by the mouth applied to the nostril of the patient, if no other instrument can be procured. A tube may be constructed by rolling a piece of the sole of an old shoe, or paste board, and securing it round with thread; and then inflating the lungs by applying the mouth to one extremity of the tube, the other being inserted into the nostril. The pipe of a common bellows may be inserted into one nostril, whilst the other side and the mouth are closed, the cartilage of the trachea is

* See Ann. Repts. of the Roy. Hum. Soc. 1803.

pressed backward to prevent the air from getting into the stomach, and as soon as the lungs are filled, they are again emptied by pressing on the sternum. Their motions should also be regular and uniform, as it has been proved, that, when the air is retained by the lungs in a state of extreme distention, its qualities are less changed, in a given time,* than when breathed by alternate inspiration and expiration.

When the common bellows is used, the air should be discharged in expiration from the opposite nostril, otherwise it returns into the bellows and again into the lungs; the construction of this instrument prevents its exit by the valve on the side. In inflating the lungs of animals, with the single bellows, I have observed the precaution of pressing open the valve with the finger before the air was injected, and then forcing that which remained in their cavity through it, and afterwards continued the inflation. This precaution obviates all the disadvantages of the single bellows. The double bellows of Hunter, however, from its convenience, is to be preferred. An instrument has been invented by Mr. Field of London, by which the lungs are entirely collapsed, in order to expedite the circulation. The alternate and complete

* Ellis's Enquiry, Edin. 1807.

exhaustion of this viscus of its air, as mentioned in a preceding part of this essay,* is not so favourable to the oxygenation of the blood as natural respiration: any other process, therefore, than simple inflation is improper; particularly as it is very doubtful whether the circulation is really advanced by entirely collapsing the lungs more than by natural respiration.†

With regard to the kind of air to be used, there can be no doubt upon the subject. Pure oxygen, nitrous oxide, and all the gases, excepting atmospheric air, are proved to be unfavourable to life.‡

As to the number of respirations, the Humane Society of London advise twenty or thirty in a minute; as the imitation of natural respiration as nearly as possible is desirable, ten are amply sufficient. The cooling of the blood by the extensive surface exposed by the lungs, and its complete oxygenation, are circumstances always to be kept in view.

If the respiration be too frequent, the blood loses its temperature; if too slow, it is not oxygenated in the greatest possible degree, and as this last process takes place, even after death, these circumstances are not imaginary; particularly too,

* See p. 31. † See p. 51.

‡ See pages 35, 39, et seq.

as it has been shown, by actual experiment, that artificial respiration, if not too rapid, retards the loss of temperature after death.*

In performing artificial respiration great force, in injecting the air, must be avoided, from the danger of penetrating their texture,† and after it has been continued for some time and resuscitation is commencing, the number of respirations may be increased, as we have before shown that the quantity of blood in the arteries is by these means augmented.‡ Extreme distention of the lungs in this stage is to be avoided, not only as it is incompatible with the process of oxygenation in its most perfect degree;§ but also as it may produce emphysema and a fulness of the vessels of the brain by retarding the course of the blood; a circumstance worthy of attention, as it frequently causes apoplexy, even in healthy subjects.

Condensation of the atmosphere to four times its usual density is said to produce increased quickness of the circulation, and to empty the cava and the right ventricle, of course, to fill the lungs with blood, an indication certainly desirable to be fulfilled.

A bladder was tied to a pipe, which was insert-

* Philips' Enq. p. 215.

† See p. 33, and Expts. 41, 42. ‡ See p. 52.

§ Ellis's Enq. Edin. 1807, and p. 31 of this essay.

ed into the trachea of a kitten; a strong and uniform pressure was made upon it so as to distend the lungs; the animal died after eight minutes. The lungs were kept distended by a ligature made round the trachea, the heart beat more strongly than had been observed in animals killed in any other manner. There was also no distention of the cava and sinus venosus, and there was a large quantity of blood in the left auricle.*

These changes were to be expected from opening the thorax immediately after death, for as the power of the heart continues still considerable, it is evident that the circulation through the lungs must, of course, exhaust the vena cava of its blood, but as the lungs, in their most distended state, can exert but little pressure on the vena cava, it is clear that the effect of condensation of the air can be very slight in emptying either the cavæ or the right side of the heart, in which they terminate. Accordingly, from my experiments performed on cats, some hours after death,† no effect was produced on the right side of the heart, when the lungs were forcibly injected with air, because that organ had ceased to pulsate. The blood is pretty equally divided between the right and left sides of the heart, (if only ordinary distention is

* Kite, London. † See Expt. 41.

applied to the lungs,) and is the effect of the power of the circulation alone.* It is, then, certain that condensation of the air in the lungs can have little effect on the circulation; and as, when considerable, it renders emphysema probable, it is certainly dangerous.

The use of Hunter's bellows with ordinary pressure is most advisable. Munro recommends a pipe like a common male catheter to be introduced into the trachea; Mr. Coleman added to a tube, with a vegetable bottle fixed to one end, a director made of a conical piece of ivory to secure its passage into the trachea. This apparatus, however, is entirely unnecessary. A large tube, as recommended by Monro, with a thick wire in the inside to give it firmness, and slightly curved, may be thrust into the œsophagus below the epiglottis; the tongue is next drawn out and the instrument retracted, as if it were intended to be drawn out of the mouth, keeping it in a line along the middle, but raised from the tongue. With this precaution it readily descends into the glottis; the irritation, produced on the internal membrane of the trachea, offers no objection to its use, because even in health, when the irritability is great, it ceases after the first violent effort. A tube intro-

* See Expt. 7.

duced into the trachea prevents air from passing into the stomach, and thus the descent of the diaphragm continues free and respiration unimpeded. The functions of the brain would also, on recovery, be weakened by the extreme distention of the stomach.

If the introduction of the pipe be impossible, which is not probable, bronchotomy should be immediately performed; a longitudinal incision must be made three or four rings below the cricoid cartilage, the trachea divided between the rings, and to prevent the blood from flowing into it, the superficial veins are to be avoided and the head kept in an erect posture. Mr. Justamond, a celebrated surgeon of London, performed this operation on a boy who had been drowned; the discharge of blood into the lungs, through the opening in the trachea, was so copious that recovery was impossible.*

With regard to the use of inflation of the lungs with atmospheric air, I have made many observations; alone, it certainly will not resuscitate animals, a result which corresponds with the observations of Bichat. Continued for about half an hour in temperatures of 61°, of 70°, of 80°, there

* See Obs. on Anim. Life and Appar. Death, by John Franks, 8vo. 1790, London, as quoted by Currie.

appeared to be some promotion of the circulation. In another instance, in air of 62°, the circulation was not at all improved; in air of 100° there was more blood than usual in the arteries;* in one instance, though the power of the heart was apparently increased by inflation for fifteen minutes, the circulation was not in the least advanced.†

These are the natural means of increasing the heart's motion; of the modes proposed by art, galvanism has promised much. By Oswald it was applied by a machine, composed of two hundred and thirty pieces of zinc and copper, at the same time that oxygen was inspired; the greatest period of submersion was six minutes; in several cases he was successful, and he failed but twice. This result I confess I think questionable: the respiration of oxygen alone destroys life, when in full vigor, according to the experiments of Davy, in a very short time; weakened by submersion, its effect must be more decided. Dr. Philips has proposed to conduct a stream of galvanism through‡ the lungs in the direction of their nerves, and for this purpose he states that the power should not exceed fifteen, or at most twenty-four inch double plates of zinc and copper, the fluid

* See Expts. 39, 40, 36, 43. † Expts. 16, 37.

‡ See Philips' Exp. Enq. p. 329, Phil. 1818.

being one part of muriatic acid and water. The application of galvanism and electricity through the great nerves leading to the heart and lungs appears to be useless; the heart is certainly not susceptible through its nerves, if the stimulus be applied to the eighth pair in the neck, as is the case with the voluntary muscles. The experiments of Bichat, Fowler, and Humboldt prove this position; according to the two latter, it is necessary that the influence be applied to the nerves a short distance from the heart, a circumstance which renders it probable that this influence did not, in their experiments, pass through the nerves at all, but was conducted directly to the muscular fibres, particularly as Bichat found it impossible to produce contractions in the heart when the brain and heart were armed with different metals, also the medulla spinalis and the last organ, and, finally, the same organ and that branch of the par vagum, from which it receives several nerves. The two armatures were made to communicate, and no sensible effect resulted; the best mode, then, of influencing the heart's motion is by applying the stream directly through the thorax, commencing as nearly as possible to the heart. This

remedy has been used successfully in resuscitation of animals asphyxied from cold.*

Electricity also promises something in this disease: eggs have been hatched by it in forty-eight hours;† Abilgaard found that small promote, but that large shocks prevent recovery.‡ Coleman states that the hearts of young animals have been made to contract, by electricity, from ten to fourteen hours. The muscles were agitated violently from four hours after submersion by applying powerful shocks of electricity; in another subject, the heart and arteries were roused for a moment, and afterwards excitement was impossible by any stimuli.§ Kite found that small shocks lessened the irritability of the heart and muscles;‖ the effect was powerful; it emptied the organ of blood when inflation had no influence.¶ In these experiments, small shocks of one-third of an inch, from a phial containing twenty-four inches of coated glass, were sufficient.** From these facts it would appear that the exact power of electricity, as a means of resuscitation, is not known. It has been used in other cases, besides death from submersion, with good effect. A child, aged three

* Oswald, p. 70.

† Mem. de l'Acad. de Berlin, quoted by Fothergill, p. 137.

‡ Ibid, p. 123. § Kite, London.

‖ Ibid. ¶ Ibid. ** Ibid, 87.

years, fell from a height and was taken up to all appearance dead; electricity was applied, after twenty minutes, to the thorax, by passing shocks through it, and soon after the pulsation of the arteries was perceived; the child vomited in ten minutes, and was restored, in about a week, to health. According to my experiments, electricity, applied in a stream in air of 56°, increases the power of the heart; broad surfaces, as conductors, contribute to this effect more than points,* and sparks not at all. Opening the pericardium causes the heart to beat, after it has ceased to be influenced by electricity;† inflation also increases it with this combination. Electricity, by sparks, and a stream both increase it, when exposed to the air, by opening the pericardium;‡ electricity has no effect upon the heart when transmitted by the eighth pair of nerves,§ nor in resolving coagulated blood, an indication important to be fulfilled, as sometimes the power of the heart continues after coagulation of the blood takes place.‖ It is, then, most properly applied in moderately strong shocks by passing it through the thorax in a stream, and after inflation has been used for some time.¶

* Expt. 54.
† Expt. 50.
‡ See Expt. 62.
§ See Expt. 50.
‖ See Expt. 55.
¶ See Expts. 48, 50, 55.

With regard to the effect of other stimuli upon the heart, I have made some observations. Water, at 120° of Fahrenheit, applied in a bladder near to it, has no effect whatever on that organ.*

The agency of ligatures applied to the extremities, so as to limit the circulation to the vital organs, is very encouraging. A cat submersed till death, and exposed in air of 100° to 110° for thirty minutes with atmospheric inflation, and ligatures surrounding the extremities, so as to limit the circulation, greatly increased its power in the trunk.† With the same combination in a temperature of 110° for one hour, the same effect was produced:‡ and also in another, in air from 100° to 110° for the same time; in another, in air at 60° for forty minutes, the circulation was equally increased, proving clearly that ligatures, limiting the circulation to the trunk, greatly increase the power of the heart. The effect of the ligatures in increasing the power of the circulation was very decided, for in one instance all the extremities were surrounded by ligatures but one, and in the latter there was less blood in its artery at its passage into the limb, proving that if the ligatures had not been applied, the circulation would not

* Expt. 52.

† See Expt. 45.

‡ See Expt. 46.

have been increased in all the large arteries which supply the trunk, as it would have been diffused through the extremities: as distention of the arteries and the left side of the heart is necessary in order to cause the valves to perform their functions, and as, in asphyxia, the blood is confined to the venous system, the difficulty of procuring a sufficient quantity of blood to fill the arterial system, must be evident, and the value of the application of ligatures to the extremities, as it tends to produce that effect, and, of course, to increase the power of the heart,* is also apparent and certain. In these experiments, atmospheric inflation was used in order to produce a sufficient power of the heart, and distention of the blood-vessels to found a comparison, on which to determine the effect of circumscribed circulation; without it, it had been observed that there was no circulation of blood, even in the armpit,† in consequence of the weakness of the heart: and as atmospheric inflation alone had been observed not to increase the powers of the circulation in an equal degree, as when in combination with circumscribed circulation, the effect of the latter was clearly evident and certain.‡

* See p. 20, 55. † See Expt. 35.

‡ See Expts. 37, 39, 40, 43, and the subsequent experiments

During these operations, and after circulation has commenced, frictions may be applied with propriety to the body; as it has been shown by direct experiment that they increase the quantity of blood sent to the right auricle, the distention of which weakens its power, after asphyxia has taken place, the postponement of this remedy, till the blood has begun to circulate, appears evident and proper; also as friction retards the passage of blood by the arteries, as much as it facilitates that by the veins, it should be gentle, and great pressure should be avoided upon the bowels: it will be best applied by the hand moistened with oil or lard; a brush has been used to excite the surface, and whipping with rods recovered a case recorded by Justamond. Sal ammoniac, oil of vitriol, and common salt, all substances which may destroy the texture of the skin are improper. A boy died after immersion, for fifteen minutes, in a pit of salt lye; it produced inflammation of the skin, and of the whole tract of intestines. This substance, if used in frictions so as to destroy the surface, and till the circulation was established, would constantly produce this effect.

The flour of mustard, the essential oil of tur-

on the effect of ligatures combined with atmospheric inflation, 45, 46, &c.

pentine, boiled over cantharides, may be used; the room, however, must be well ventilated when substances of an acrid and volatile nature are applied, as the person may have an idiosyncrasy with regard to them, in which case, the want of ventilation might be injurious. With regard to the action of remedies of this character, it may be observed that as the most violent are necessary to excite the body when in asphyxia, and as their operation may be excessive, when life returns, it is necessary to abate their action by washing the skin, as it regains its sensibility. Volatile liniment, composed of equal parts of olive oil and vol. spirits of ammonia, will, perhaps, be the best application, as it will not incommode, and will stimulate sufficiently. The parts to which it should most properly be applied are the trunk, particularly opposite to the stomach and heart.

The operation of mechanical stimuli, as a brush, when they induce inflammation, has been observed to render the animal more sensible to galvanism;* this circumstance demonstrates the propriety of deferring this stimulus till the circulation is established.

The vapour of vinegar, applied to the conjunc-

* See Fowler's Expts. and Observat. Edin. 1793. p. 128.

tiva,* rouses from syncope; light thrown upon the eyes, volatile alkali applied to the inside of the nose, loud noises, acrid substances to the tongue, as prepared mustard or the juice of onions, may be useful. Tickling the soles of the feet, the sides and arm-pits, as also the nose, with a feather,† are recommended; they, however, can only be useful after circulation commences, as the passage of blood by the arteries is necessary to establish the sensibility. Plucking the hairs‡ has also been suggested, and it appears equally reasonable with beating with rods, which has succeeded. It is in this stage of the treatment that agitation of the arms promises benefit by stimulating the heart from its effect on the vessels.§

With regard to the use of internal remedies, the essential oil of mint, peppermint, and other aromatic stimulants, appear to be best adapted to the system in this species of asphyxia; injected into the stomach, they produce exhilaration without any dangerous effect. Laudanum is noxious from the difficulty of graduating the dose, as large quantities must be used in this disease; six drachms of laudanum were followed by an instan-

* See Bichat's Phys. Researches, p. 244, Edin. 1809.

† Cogan's Amsterd. Memoirs. § Expts. 36, 54.

‡ Kite, 1788, Lond.

taneous diminution of the motions of the heart after its injection into the stomach;* six ounces of brandy rendered more quick and feeble the pulsations of the heart according to the same author; he also states, they produce their effect before respiration, and, of course, circulation is restored. Kite states that heated liquors injected into the stomach, after hanging and drowning, have no effect upon the brain.†

According to my experience, the effect of the same agents injected into the stomach, of turpentine, hot water exhibited no evidence of sympathy between the action of that viscus and the heart after submersion.‡ Electricity also passed through the stomach, was equally ineffectual.§

It is evident they can produce no effect till the circulation is established; it is, therefore, necessary to postpone their application, and thus the danger of giving a quantity which may embarrass the functions of life will be avoided, as the effects can be immediately observed; as soon as symptoms of resuscitation appear, water with a little æther, Hoffman's anodyne liquor, brandy, or wine

* Coleman, 1802.

† Mem. Soc. Lond. vol. iii. quoted by Fowler p. 72 of Expts. and Obs.

‡ Expts. 60, 61. § Expt. 62.

may be injected into the stomach with the best effects.

The use of tobacco in injection has long been recommended: Coleman gave it to a drowned puppy* after all motion had ceased. One drachm of tobacco was infused in two ounces of boiling water and suffered to cool. With the common means of recovery it soon made efforts to inspire, and breathed tolerably well, but in less than ten minutes it died; as the same quantity given to a small dog in health produced death in less than four minutes, and as it would have endangered even the life of a man, the dose was certainly fatal; no conclusion, therefore, with regard to the powers of the remedy in a proper quantity, can be drawn from these experiments.

Legare tried the effect of tobacco injected into the intestines; he found that nausea, and vertigo were the first symptoms; on exposing the intestines some time after submersion no peristaltic motion appeared, even after five minutes irritation by the air, and when tobacco fumes were injected of the temperature of 90° of Fahrenheit, the lacteals became visible and turgid, the peristaltic motion was more considerable, and the arteries beat more strongly after every injection; after thirty-

* Coleman, 1802.

six minutes the remedy lost its power from the exhaustion of the animal.* Administered of the temperature of 65° by the anus it produced the same effects, increasing the pulsations of the mesenteric arteries, whilst the carotids beat as usual.

The injection of warm water into the bowels, at the temperature of 130° and 65° of Fahrenheit, increased the peristaltic motion in animals whose abdomen was simply opened without any other injury.

In animals submersed for one and a half minute and for three minutes, no effect was produced by the tobacco fumes, though they were continued for an hour, united with artificial respiration; in another, with heat and tobacco fumes, they were equally inefficacious. The fatal effects of tobacco, when administered in ruptures, proves the necessity of caution in the use of this remedy. The Abbe Fontana found that a small quantity of the essential oil of tobacco, applied to wounds, palsied the limbs. Accordingly, we may conclude, from these observations, that this medicine, like opium, in large doses is speedily distinctive, that in moderate doses it first stimulates and excites the powers of life. Like other substances of the same class its use should be restricted till the re-

* Legare on the effects of tobacco fumes, Phil. 1805, p. 15.

establishment of the circulation, and then it should be given in the most cautious and moderate manner. Dr. Hawes has invented a machine for injecting tobacco smoke into the intestines; a common clay pipe, to the bowl of which the mouth may be applied, answers very well. Other stimulating substances are recommended; Currie advises an injunction of two or three tea spoonfuls of spirit of hartshorn, a heaped tea spoonful of mustard, or a table spoonful of essence of peppermint with a sufficient quantity of warm water; these may be continued after some degree of vital power has been restored and the sympathies of the system have been, in some measure, established.

With regard to the use of emetics, they should be postponed till the circulation returns: that the stomach is insensible to white, to blue vitriol, to emetic tartar, after the usual signs of life had disappeared, has been proved by actual experiment. One drachm of tartarized antimony, given to an animal submersed till all struggling had ceased, produced no effect upon the internal coat of the stomach or intestines.* When symptoms of recovery began to take place, vomiting and purging were the consequence. The animal, however,

* Kite, London.

died at the end of seventeen minutes from the commencement of recovery; and it is probable that death was produced by the excessive dose. White vitriol and emetic tartar, thrown into the stomach, diminished the force and frequency of the contractions of the heart, a fact which renders it highly probable that these medicines are entirely useless or dangerous in this disease. They produce great irritation from the necessary dose, and are therefore unmanageable, and when they do operate they weaken, and when they are retained they destroy the powers of life.

As to the propriety of venesection when the vessels of the face are extremely turgid, and there has evidently been great determination to the brain, it may be proper, as the symptoms of recovery begin to appear, to bleed in the jugular vein, and thus relieve any congestion which may exist there; but the quantity must be such as not to debilitate the patient. As it is certain that emptying the cava promotes the motions of the heart, and as opening the jugular vein will produce this effect, it is a measure which may be sometimes useful, even before symptoms of resuscitation take place, and may be practised as soon as inflation is commenced. After recovery has taken place, should pain in the head, giddiness, drowsiness continue, it may be proper to draw blood from

the jugulars, or apply leeches or cups to the back of the neck; in general the latter will answer every purpose. Kite drew blood in forty-five cases, according to the London reports, with favourable effect; it has been recommended by Coleman when the patients are plethoric, and it is necessary to be particularly cautious in tying up the arm after bleeding, as Cogan* relates a case, in which the patient bled for some hours after this operation in such a manner as to insure death.

With regard to the effect of the transfusion of blood on the drowned, it has been conjectured† that eight or ten ounces of blood will produce resuscitation when injected into the jugular vein; but it is evident that as the cause of death is owing to the formation of improper blood, even if arterial blood were injected, this quantity would be too small to produce any effect, and into the jugular vein it would be useless, because, in the most natural state, arterial blood is unnecessary there, and what is still more discouraging, even if the whole arterial system could be filled with scarlet blood, and not constantly renewed as it changes its colour in one and a half minute, it is

* See Cogan's Translation of the Dutch Memoirs.

† See Rep. of the Hum. Soc. Lond. for 1785-6. Sherwin's Letters, p. 204.

probable that resuscitation would, by these means, be little assisted.

However, it is stated that resuscitation took place, in an experiment performed by Dr. Gartly, by the transfusion* of arterial blood. Bichat failed to produce resuscitation by injecting arterial blood into the brain, because the blood was not renewed by its union with oxygen:† if the motions of the heart were entirely suspended, the injection was of no avail; the animal could not be recovered after that change had taken place. It is evident that the practice of continued transfusion of arterial blood would fulfil all the indications necessary to be observed; the arterial blood, if renewed in the blood-vessels, would supply the stimulus of distention, as also the proper fluid for the support of life; and to produce this effect, the body of one animal may be used as the means by which the circulation may be continued through that of another. Accordingly, from the well founded prospect of success afforded by this remedy, some experiments were made, but from the coagulation of the blood in the tube, which takes place very soon, even at temperatures nearly equal to the animal body, I was unsuccessful.

* Oswald, p. 20.

† See Bichat's Phys. Researches, p. 202-3.

From the probability of pernicious effects from the influence of the blood of other animals upon the human system, and the general impossibility of procuring transfusion by means of the body of another person, the experiments were relinquished.

ON THE

CURE OF ASPHYXIA

FROM HANGING.

This disease has been shown to differ from drowning, only in the effect of the water, which conducts away the heat of the body more rapidly. The same modes of cure are to be pursued. A physician assured the great Bacon that he could revive, by tepid baths and frictions, any subject who had not been suspended longer than half an hour, when the neck was not dislocated.* The same remedies have succeeded in recovering the drowned; cupping glasses, to abstract the blood, are frequently advisable, from the accumulation of blood in the head. Sometimes children are suffocated by being covered in the bed-clothes. It is common to permit cats to sleep in the bed, or

* Struve's Pract. Essay, p. 37. Albany, 1803.

on the cradle with young children: Attracted by the pleasant temperature, these animals lay themselves across the neck of the child, and thus completely obstruct respiration. In these cases the remedies for resuscitation are the same.

ON THE

CURE OF ASPHYXIA

FROM NOXIOUS VAPOURS.

When a person is exposed to carbonic acid gas he becomes drowsy, inclines to vomit, and has a headach. The sleep becomes deep, and at length the patient is insensible; his breathing is natural, without any symptom of suffocation; and if he is not relieved within an hour he is irrecoverably lost.

In treating this disease, all the above modes must be pursued, with this exception; as the body is generally soon recovered, and the air is not so good a conductor as water, the temperature is greater than in cases of drowning; the application of cold water, let fall from a height, or thrown in small quantities with some violence against the surface, drying it at intervals, has succeeded. If it be winter, frictions with ice and snow may be applied. Inflation with atmospheric air; galva-

nism; electricity; and the other remedies for asphyxia, produced by submersion, must also be used. Injection, into the lungs, of air impregnated with volatile alkali has been proposed, by Mr. Safe, in death from fixed air. It is probable that it operates by stimulating the olfactory nerves, and by sympathy, the diaphragm and intercostals.

ON THE

CURE OF ASPHYXIA

FROM COLD.

In high northern latitudes, parts exposed to extreme cold become insensible, livid, and after some time entirely lose their life. The person affected is ignorant of his situation till informed of it. The most effectual remedy is to keep the parts in a low temperature by rubbing them with snow or ice, taking care not to break the skin, and gradually and slowly raising the temperature. When the patient has been wholly frozen, the same plan of treatment must be followed; he must be rubbed or covered with ice or snow till the symptoms of recovery begin to appear; flannels sprinkled with volatile stimuli, as the spirits of ammonia, should be applied and rubbed over the surface. As the appearances of life advance, the preceding means of resuscitation must be used, observing

that the temperature should be *gradually* and slowly raised in proportion to its former depression. This disease differs from asphyxia from submersion in being attended with general debility of the powers of life from the loss of temperature; the destruction of respiration being merely a consequence of that reduction. Hunger frequently concurs in producing this species of asphyxia, and is cured by the *gradual* exhibition of nourishing substances; equal caution in their exhibition is necessary, as in asphyxia from cold with regard to the application of heat. When it is the sole cause, recovery is generally impossible from the excessive debility it produces. Ardent liquors often unite with cold in suspending life. In Russia it is observed that the use of spirituous liquors, in cold weather, are followed by a debilitating chill which favours the baneful effects of cold: accordingly, in excessive frosts they are avoided.* Immersion in cold water, and afterwards rubbing with snow, are the most effectual remedies. When the extremities are frozen in Russia, even when quite black, rubbing the parts with goose grease has been found to restore their life and circulation with great effect.

* See Travels from Petersburg to divers parts of Asia, by John Bell, vol. i. in the years 1715-18.

Mr. Currie, in his book on this subject, mentions that after the taking of Ochakoff some prisoners were cured by this application by the peasants, when others, under the care of the regular surgeons, lost their limbs and toes by the use of other means. The goose grease was smeared over the parts while warm, and the operation was often repeated, so as to keep them always covered with the grease. The circulation gradually extended lower down, the blackness disappeared, and by degrees they became perfectly well.

ON THE

CURE OF ASPHYXIA

FROM LIGHTNING.

When this cause has acted with great power, disorganization takes place: hemorrhages occur at the mouth and nose; the blood-vessels are ruptured; the pia mater is torn in pieces; the brain is altered in its appearance; the skin is black as ink and driven into ridges, and speedy putrefaction takes place. In such cases recovery is impossible; it is only when no organic lesion of the organs is produced, that there is any prospect of cure.*

The violence done to the surface of the body may be considerable, without necessarily rendering recovery impossible. A man was struck by lightning, which threw him upon his back several

* Kite, p. 235, London, 1788.

yards within the room, with his legs upright in the air, in which posture he remained for a long time, perfectly sensible but unable to open his eyes or to speak; he could not move his limbs for some time afterwards; his clothes were rent in many parts; brass buttons and part of his watch chain were melted; the flesh of his right side scorched and torn; and one of his toes split open, and yet his breathing was not suspended, nor any future injury sustained.* A boy, struck by lightning, was carried home apparently dead; the body was stiff, cold, the countenance livid, and the eyes contracted; by bleeding to twenty ounces, the use of a warm bed, and strong frictions, he recovered in a short time; cooling remedies and purging removed a fever which followed, and in a week he was well.† Electricity has been used with success. M. Abilgaard recovered fowls struck down by an electric shock through the head, by another shock through the breast and back; a second shock given to the head had no effect; that through the breast restored them, even after the blood flowed from the nostrils.‡ It would be prudent to make

* See Currie's Observations, p. 146, quoting the Phil. Trans. 1781, vol. lxxi. p. 42.

† Trans. of Roy. Hum. Society, vol. i. p. 198.

‡ See Collect. Soc. Med. Haun, tom. ii. quoted by Currie, p.

the shocks at first gentle, and gradually increase their power. Inflation of the lungs and heat to the surface, should the body have cooled, will be useful assistants. Stimulating glysters and drinks may also be advisable.

Exposure to rain, as in the asphyxia produced by other causes which do not diminish the heat of the body, has succeeded.* Bleeding, inflation, frictions, emetics, the earth bath, have also been used.† To avoid danger in a thunder storm, avoid trees, palisadoes, or any elevated object which may attract the lightning; it is better also to be thoroughly wet by the rain, as electricity passes harmless over any substance whose surface is wet. Leaden spouts, iron gates, iron stoves, windows, bell wires, are dangerous during a thunder storm.

148. Electricity recovered a boy who was apparently dead by a fall, after other means had failed.

* Fothergill's Preserv. Plan, p. 18. † Struve, p. 145.

ON THE

CURE OF ASPHYXIA

FROM FEVERS.

This form of the disease has also been cured by exposing the body to water falling from a pump.* The other remedies are also applicable.

A patient had a fever for nine days, was seized suddenly with debility; the physician, on his arrival, found him without pulse or respiration, and was told that he had been in that state for a quarter of an hour. The feet and stomach were fomented with hot brandy, and half a pint of Madeira wine was given him. A tremulous motion was observed in the under lip, and soon after he began to sigh and the pulse to beat; he became sensible, and soon recovered. Coughing sometimes induces asphyxia. A child, labouring un-

* How. Append. p. 125, quoted by Kite, Essays, p. 383, 1795, Lond.

der a cough, was suddenly attacked with a difficulty of breathing, and to all appearance died; it was gradually recovered by inflation of the lungs. The same remedy was applied several times and with the same success. The attack recurred in the absence of the physician, and the patient died. Fainting, induced by any cause, when the person is much debilitated, will suspend life, and if proper means are not used will end in death. A woman, after delivery, fainted suddenly; the maid servant extended herself upon her mistress, inflated her lungs by blowing into her mouth, and she soon recovered. On enquiry she said that at Altenburg midwives practised this method on children with the greatest success. This corresponds with the method of Elisha used for the recovery of the Shunamite's son, 2 Kings, c. iv.

ON THE

CURE OF ASPHYXIA

FROM PRESSURE OF THE UMBILICAL CHORD.

The death of infants is often produced by the too sudden rupture of the membranes, and the consequent protrusion of the chord between the sides of the pelvis and the head of the child. Death, in this instance, results from the stoppage of the circulation by the placenta: it does not arise from apoplexy, because it would not be so instantaneous; nor from suppressed circulation *in the lungs*, because the same state of these organs will always exist; nor from the want of nourishment, because the child may be supported for several days without it.* Asphyxia in children may also be pro-

* See Dr. Clarke in Rep. of Hum. Soc. Lond. 1785-6, taken from the 8th vol. of Lond. Med. Jour. and quoted by Kite, 1788, Lond.

duced by the death of the mother. Doleus mentions that signs of life continue for a day after this event; a child was saved forty-eight hours after the death of the mother, though it was wounded in the foot.*

Mr. Locock mentions a case in which a child remained exposed to the cold on a table in a wash house for something less than two hours; he placed it on his knees before a fire, chafed it gently, and applied brandy to the stomach, occasionally inflating the lungs for more than half an hour. The umbilical chord began to bleed, the heart to beat gently, the same means were continued, and the child gradually recovered.†

The remedies are the same as in other cases. The use of ammoniacal vapours recommended by some practitioners is dangerous, as they may sometimes destroy life. A current of cold air or cold water sprinkled over the body have been sometimes effectual, particularly where asphyxia has been produced by smothering under the bedclothes.

* See Osiander, quoted by Struve p. 37, and Kite p. 249, Lond. 1788.

† See Currie's Obs. on Ap. Death, Lond. 1815, p. 138.

REMEDIES

FOR ASPHYXIA

FROM EXCESSIVE INTOXICATION.

With regard to the cure of suspended animation from excessive intoxication, the patient should be laid upon a bed with his head a little raised; his neckcloth and all tight bandages round the body loosened; the body should be rubbed with flannels, and the liquor removed from the stomach by an emetic or by a pipe and syringe.

The emetic may be introduced by means of the pipe and syringe, and should consist of ipecacuanha, emetic tartar, or of white or blue vitriol. Thirty or forty grains of ipecacuanha infused in boiling water, or three grains of emetic tartar, twenty of white, and five of blue vitriol, may be given, and repeated at intervals of ten or fifteen minutes. I have seen a child, who had taken half a pint of gin, completely recovered, and the sto-

mach more effectually and suddenly evacuated by equal parts of sweet oil and sweet milk, given at a short interval in the quantity of a teacup full, than by any other mode: the effect was instantaneous: The stomach was evacuated without effort, as soon as the mixture was swallowed. Should no emetic medicine be convenient, the flexible tube may be used: it should be about four feet long, introduced into the stomach, which is filled with water by pouring it into a funnel at the top of the tube, or by injecting it with a syringe: as soon as the stomach is full, the pipe may be converted into a syphon by turning down its upper extremity, and the water be again evacuated. Remove all bandages from about the neck, apply cups or leeches to the sides of the head, should it be turgid with blood; the hands and feet should be next put into warm water.

Whipping with rods may be useful; the same directions apply to the treatment of insensibility from opium, stramonium, and all the other narcotics. The stomach soon becomes insensible, and emetics do not operate after these substances have been taken. Affusion of cold water has been found to rouse the system, after the ordinary emetics have failed without it. If the patient is near a pump, let the water be discharged over

him, after a dose of emetic medicine, and it operates directly.

Mr. Brodie has proved that alcohol, of course all spiritous liquors, porter, ale, cider, wine, &c. vegetable poisons, as opium, act upon the brain and cause the diaphragm to cease its motion, whilst the vascular system and the heart continue their functions as before. He also ascertained that the heart and arteries would continue their functions if artificial respiration were kept up after these which were given; the conclusion was natural, that by the inflation of the lungs long continued, the animal might be revived, as actually took place after the woorara; the oil of bitter almonds had been administered to a rabbit and a cat; in one by continuing respiration for sixteen minutes; in the other for one hundred and sixty minutes, recovery took place. He therefore proposes inflation of the lungs as a remedy in these cases.

It is necessary that the temperature of the animals should be kept up during inflation, as this process tends to abstract the heat rapidly, when the functions of the brain have been suspended by the agency of narcotic or spiritous substances.

THE HISTORY

OF

HUMANE SOCIETIES, AND AUTHORS ON RESUSCITATION.

An account of these institutions and works, as the most valuable contributions to resuscitation from asphyxia, will be proper here. In Egypt, Greece, and Rome, it was practised with success, but no institutions were established especially for that object. In the year 1637 a dissertation was published by Peter la Sena on death from submersion;* two treatises are mentioned previous to the year 1700; in 1651 Kirchmayer wrote upon this subject, but his efforts were lost, and it was reserved for the last century to commence, in a scientific and effectual manner, this noble work.

* La Sena Petri Diss. 1637. See Trans. of the Roy. Hum. Soc. from 1774 to 1784, and Struve's Pract. Essay, 1803.

In 1767 Reaumur reported several instances of resuscitation; in Amsterdam, a humane society was established in the same year; Milan and Venice followed. The Empress of Russia published an edict for the same benevolent purposes; France, Germany, England, North America, and the states of Barbary united in the same career, and increased the distinction of the eighteenth century. The tracts of Winslow and Bruhier in France, and several minor writers in Germany, prepared for the work of Hufeland in 1791, and those of Bichat, Portal, and the Institute; Goodwyn, Kite, Coleman, and Fothergill received honorary distinctions from the Royal Humane Society of London; and in North America, the University of Pennsylvania has produced some respectable dissertations on this subject.

THE

APPARATUS AND MECHANICAL MEANS

PROPOSED FOR THE CURE OF ASPHYXIA.

1. *Of the London Humane Society.*

Fig. 1, 2, 3, are representations of a pair of bellows for inflating the lungs, as also to inject a warm stimulating vapour, as rosemary, &c. valerian.

The mark, &c. A, fig. 2, is a lever for filling the bellows with fresh air in inflations, which must be turned over in inflating it, and turned aside when the bellows are used as common bellows for injecting stimulating vapours.

C, fig. 2, is a brass nozzle which fits into fig. 3, at D, for inflating, and into fig. 6, at E, for injecting stimulating vapours.

Fig. 4, is a long flexible tube of the same description as fig. 7.

Fig. 5, is a short flexible tube filled to the nozzle of the bellows.

C, for inflating its tube F, fits into figures 8, 9, 10, 11, 12.

Fig. 6, is a brass box inclosed in wood to contain the stimulating substance, and is to be connected at E with the nozzle of the bellows, fig. 1, and at H with the long pipe, fig. 7.

Fig. 7. A long flexible tube which, being fitted at G, upon fig. 6, at H, is used for injecting with smoke.

Fig. 8. A curved silver pipe to fit on fig. 5, for inflating the lungs by passing it down the throat beyond the glottis.

Fig. 9. A canula for bronchotomy; it fits on fig. 5, at C.

Figs. 10, 11, 12, are nostril pipes of various sizes; they fit on fig. 5, F.

Fig. 13, are clyster pipes of different sizes; they fit on fig. 7, at I.

Fig. 14, is a syringe with a flexible tube K K for injecting cordials into the stomach.

This apparatus is contained in a chest lined with baize, with proper receptacles for sponge, flannels, flint, matches, steel, and tinder; and it is used in the following manner:

When inflation is intended, the circular piece of wood, B, fig. 3, is turned over the clack-hole;

then fix the short flexible tube, fig. 5, Plate II. to the brass nozzle of the bellows, fig. 2, at C; the ivory pipes, figs. 10, 11, 12, for the nostril; the curved silver pipe, fig. 8, for the throat; and the silver canula, fig. 9, for bronchotomy; each of which, as before described, is adapted to the plug of the short flexible tube.

When you wish to inflate, press the brass lever, A, fig. 2, open the bellows; then let go the lever, and, by shutting the bellows, force the air into the lungs. To extract the air, open the bellows without touching the lever; and to expel the foul air, press the lever, (to open it) and shut the bellows, by which means the extracted foul air will be thrown away; then, still keeping the lever open, dilate the bellows, by which means it will again be filled with fresh air; let the brass lever down and proceed to imitate inspiration and expiration.

It may, perhaps, be necessary, at first, to fill two or three times before you expel once; and, for this purpose, you must remember to keep the lever open whenever the bellows are emptied, in order to take in more fresh air by the dilatation, &c. &c. When the brass lever is shut, and the circular wood is removed from off the clack-holes, it is a common pair of bellows.

ORIGINAL DOCUMENTS.

The Points examined.

Time of dying; Temperature; Peristaltic motion; State of the heart, vessels, and muscles after death.

Experiment I.

At forty minutes past eight o'clock, P. M. the thermometer standing at 85° of Fahrenheit, a kitten, about twenty days old, which had been without food for twenty hours, was immersed in water. In one minute and a half the struggles had ceased. The thermometer was applied to the skin of the abdomen, and examined, after letting it remain for five minutes, and the temperature was 92°, the surface being completely wet. In ten minutes after immersion it was 90°; in fifteen minutes it was 89°; in thirty minutes it was 88°. The abdomen was opened to ascertain its temperature. In forty minutes after immersion, the

thermometer was introduced into it, and its exposed surface covered from the air, and in fifty-two minutes after immersion, the temperature was 84°; of the room 78°. The peristaltic motion still continued, and, in three hours and ten minutes, it was again examined and it had ceased, but the blood had not coagulated: in twelve hours and eleven minutes, the motion of the heart had ceased, and, on opening the pericardium, it still continued motionless; the blood was not coagulated; the right ventricle and the large veins connected with the heart were filled with blood, though not excessively distended. The pulmonary artery contained some blood; the pulmonary veins were full; the left auricle was nearly empty; the left ventricle contained almost none; the aorta contained but little; the veins of the neck contained some; and the muscles had lost their irritability.

Experiment II.

The Points examined.

The Temperature; Dissection; Veins; Heart; Lungs; Blood vessels; Blood; Body; Brain.

A cat, about twenty days old, which had not taken food for twenty-four hours, was submersed till she died. The temperature of the room was

85°. In one hundred and twenty-three minutes, the temperature of the surface of the abdomen was 89°; in one hundred and thirty-six minutes, the temperature of the abdomen below the muscles was 92°.

The muscles had lost their irritability eleven hours after immersion.

The veins of the neck, as they descended over the lower jaw, appeared gradually to be more filled to the right auricle, which was full. The ascending cava was also full; the heart was without irritability; the right ventricle considerably distended; the pulmonary artery contained some blood; the lungs, a little air as the animal escaped during submersion, and made a partial respiration; the left auricle was very small with very little blood; the pulmonary veins somewhat distended; the left ventricle contained less than the left auricle; and the aorta some blood. The veins of the tongue also contained some, but were not distended. The blood was not coagulated, and the whole body was stiff; the veins of the brain were not distended.

Experiment III.

The Points examined.

Time of dying; Temperature; Heart; Blood-vessels; Body; and Muscles.

A cat was submersed till it died, with the intention of examining her body some time after death. Its struggles completely ceased in one minute and a half, and it was removed from the water in two minutes. The air of the room was 79½°.

In 7 minutes after removal from the water the body was at	97°
In 18 minutes	97°
In 32 minutes	97°
In 42 minutes	96°
In 63 minutes	94°
In 86 minutes	92°
In 128 minutes	88°
The temperature of the room was	79½°

The body was examined after nine hours had elapsed, and the heart and large blood-vessels presented the same appearances as in the last case; the body was stiff and the muscles had lost their irritability.

Experiment IV.

The Points examined.

Resuscitation; its symptoms; Temperature; as also of the healthy animal, and the effects of suspended circulation in the living body.

A kitten, aged about twenty days, was immersed for one and a quarter minute; it had not eaten for fifteen hours. After laying it on the table, it remained still for a few seconds, then it gasped, breathed several times at the interval of five or six seconds; in about two minutes it made motions with its jaws as if it were chewing, stretched out its legs, the abdomen exhibiting motions of convulsion; it began to move its feet, to roll and kick; seemed in pain; breathed with great effort and with some convulsive movements of the abdomen; it breathed eight minutes after immersion, forty-two times in a minute; began to mew, to move about, and express great pain.

The temperature of the room being 81° of Fahrenheit, the kitten still went on rising up to go away; the bulb of the thermometer was applied to its belly and kept close to it by wrapping a linen handkerchief round it, so as to prevent the escape of heat by evaporation. After the thermometer had been applied for ten minutes in this manner,

the heat of the surface was ascertained to be accurately 88° in about twenty minutes after being removed from the water.

The thermometer was applied successively to the bellies of three healthy kittens of the same litter; it rose in the two first to 98°; in the last to 96°, proving that there was nothing peculiar in the degree of heat of the animal.

Note. Suspension of circulation in a limb of an healthy animal produces the same reduction of temperature. In the summer of 1819 tourniquets were applied by me to the humerus and thigh, so as to compress the arteries completely, and after fifteen minutes, the temperature generally fell to 90°, 88°, and 87°.

Experiment V.

The Points examined.

The time of continuance of sense; Effects of immersion for two minutes.

A kitten was immersed for two minutes; it struggled violently, turned its eyes upwards, pawed in a direct manner up and down, pressing against the bottom of the vessel so as to raise itself to the surface for the space of forty-six seconds, when its motions became confused, its

eyes directed in no particular manner, and evidently without an object. It was taken out at the end of two minutes and gradually resuscitated.

Experiment VI.

The Points examined.

Time of continuance of sense; Effect of immersion for three minutes; Symptoms of resuscitation.

Another cat, which had been without food for twenty hours, was immersed for three minutes. On first immersion its struggles were violent; it attempted to rise directly upwards; the eyes were turned in the same direction, and its motions all tended to raise the animal to the surface; they continued for the space of one minute, and then they became irregular and directed in no particular manner. Afterwards it ceased to make attempts to rise to the surface. It made one struggle before the three minutes expired. It was removed from the water at the end of that period. In four and a quarter minutes it cried, and in four and a half it made one great convulsive motion with a deep respiration. In four and three quarters it made another; in five and a half minutes, it made a strong convulsive respiration with a general stretching of the body, froth coming out of the mouth; in six minutes, another of the same

character; in seven minutes, another with no minor respirations in the interval; in nine minutes, another; nine and a quarter, another; in nine minutes twenty-five seconds, another; it made three respirations in the next half minute; ten in the next; the breathing became now strong at about eight in the half minute; froth coming out of the mouth; the inspirations were deep; the abdominal muscles violently moved; the mouth gasping at every breath; the expirations were strong, as if the animal wished to force something through the nose; the respirations were now about twenty in a minute, twelve minutes being elapsed since immersion; it began to stretch its legs; to breathe more strongly; the power of the lungs increasing, and the general strength, till at last it recovered altogether.

Experiment VII.

The Points examined.

The effect of immersion for four minutes; Symptoms of imperfect resuscitation; Dissection.

A kitten, which had been without food for fifteen hours, was immersed for four minutes; it ceased to move directly upwards in fifty seconds; made one effort to breathe just before the four mi-

nutes expired, when it was removed. In one minute and a quarter after immersion, it made one convulsive respiration; in two and a half, another; in three and three quarters, another; in four and three quarters, another; in six minutes after immersion, another; in seven and one-eighth, another; in eight and a half, another more weak and less full; in ten and a quarter, it made another still more feeble, the strength of the animal evidently declining, when it died. In one hour afterwards, the breast was opened, the two carotids and the jugulars, the right auricle and ventricle were only moderately distended; the pulmonary artery contained but little blood; the left auricle and ventricle was moderately distended; the aorta was empty; and the blood in a fluid state. The lungs were partially distended with air, and looked red. The veins on the surface of the brain looked pale and were not full; there was but little blood in the longitudinal sinus. The muscles had lost their irritability; the peristaltic motion still continued in a very slight and scarcely perceptible degree, proving clearly that the inspirations which the cat performed before death had some effect in partially exhausting the right auricle and ventricle of blood; in filling the lungs with air and keeping the two sides of the heart more equally distended.

Experiment VIII.

The Points examined.

Immersion for five minutes; Symptoms of spontaneous resuscitation; Dissection.

On Wednesday, the 12th September 1821, a cat, which had been without food for thirty hours, was immersed for five minutes to observe the changes of spontaneous resuscitation. On first immersion, air was discharged from the lungs; the animal struggled to rise to the surface for forty-nine seconds, its face turned upwards, the feet striking against the bottom, eyes open, as if it was the wish of the animal to ascend: But after this period the head was thrown about from side to side without an object; the legs were also moved distractedly; showing that after submersion for forty-nine seconds it had completely lost the power of governing itself; it was then let loose, being still in the water, it laid on its side, stretching itself in a convulsive manner, occasionally making three or four attempts to breathe in the third minute; in the fourth fewer, in the fifth still fewer; it was then removed from the water and laid in the sun in a temperature of 75°, but no disposition to resuscitation appeared.

The abdomen was opened after the animal had laid for an hour in a temperature of 75°. The veins of the upper surface of the brain were filled with blood; the jugulars, the two cavæ, the right auricle and ventricle were also full. The left side of the heart was not so full as the right, and the arteries were empty. The muscles had lost their irritability; the intestines were slightly inflamed; the peristaltic motion was scarcely perceptible; and the sphincter ani was contracted.

Experiment IX.

The Points examined.

Spontaneous resuscitation does not take place after five minutes immersion.

Another cat, which had eaten none for thirty hours, was immersed for five minutes; one of the eyes was inflamed; the cat exhibited the same symptoms precisely as in the last case, pawing and looking up till three quarters of a minute elapsed, when it ceased to move for some seconds; at four minutes, the heart could be perceived beating in the side; immediately after the five minutes had elapsed, it was laid on a window, and it screamed out in an involuntary effort to breathe. Pressure was made on the thorax about the heart;

it gasped, which was repeated on again making the pressure. On rubbing and pressing the belly, in three quarters of a minute it gasped again; froth came out of the mouth; the gaspings became more distant and more feeble; at the end of fifteen minutes after submersion it was opened; the right auricle was pulsating vigorously; the right ventricle more so; the pulmonary artery was punctured and immediately the right ventricle contracted more strongly; the right auricle became also more powerfully contracted; but it was remarkable that the two cavæ which were laid bare, (in this and the preceding experiment the peristaltic motion had, I believe, ceased,) did not become more empty. The auricle also did not discharge its blood, or at least in perceptible quantities; the heart, then, performs its functions very inefficiently after submersion, even though its contractions continue apparently powerful. The heart continued to contract for two hours; the right auricle and ventricle much stronger than the left auricle and ventricle. When the pericardium was opened and the surface of the heart exposed to the air, the right auricle and ventricle certainly became more strongly contracted. The blood, either in the cavities of the heart, or in the great veins, did not become red.

Experiment X.

The Points examined.

Effects of six minutes immersion; Dissection.

A vigorous full grown male cat was submersed for six minutes; the temperature of the water was 75° of Fahrenheit. In forty-eight seconds it ceased to struggle with violence or to make efforts to rise; no struggles or signs of life whatever were observed after the animal was taken out of the water.

In 15 minutes after immersion, the heat of the external surface of the abdomen was	92°
In 25 minutes	92°
In 45 minutes	92°
In 55 minutes	91½°
In 65 minutes	91°
In 75 minutes	90°
In 85 minutes	87°
In 95 minutes	86°
In 105 minutes	86°
In 115 minutes	86°
In 125 minutes	84°
In 140 minutes the temperature of the interior of the abdomen was	83°

The temperature of the room at the conclusion of the experiments was 73½°.

In this experiment only the head of the cat was immersed.

On opening the body of this cat nothing peculiar was discovered at one hundred and forty-five minutes after immersion; the peristaltic motion had ceased. The iris had no contractility; the sphincter ani was contracted; the heart on its right side; the veins of the tongue, the jugulars, the descending cava, as also the ascending, were filled with black blood; the pulmonary veins were full; the left auricle contained very little, and the left ventricle still less blood; the trachea was filled with froth. The head was examined thirteen hours and fifteen minutes after immersion. The veins of the brain were found turgid with blood; the longitudinal sinus contained some air and was not completely filled; the body was stiff; and the sphincter ani was still contracted.

Experiment XI.

The Points examined.

Effects of immersion for five minutes; Decline of temperature; Dissection.

The head of another healthy, but delicate full grown cat was submersed at twenty minutes past

eight, P. M. the thermometer standing at 75°. In forty-six seconds it ceased to make attempts to ascend; it remained five minutes in the water and was removed, and exhibited no signs of life after emersion.

In 8 minutes after immersion the temperature of the surface of the abdomen was	92°
In 15 minutes	90°
In 25 minutes	88°
In 35 minutes	87¾°
In 45 minutes	86°
In 55 minutes	84°
In 65 minutes	84°
In 75 minutes	82°
In 85 minutes	82°
In 95 minutes	81°
In 105 minutes	81°
In 115 minutes	80¼°
In 125 minutes	79°
In 145 minutes after immersion the temperature of the interior of the abdomen was	76°

The temperature of the room immediately after these experiments was 73½°.

The two last experiments were performed at the same time.

The head of the cat was examined fourteen hours and twenty minutes after immersion, and

the exterior surface of the brain was found to be much darker than usual, from the fulness of the veins. The longitudinal sinus contained a considerable quantity of blood, and was partially distended. The veins of the neck, the venæ cavæ, the right auricle, and ventricle were distended with blood. The pulmonary artery was partially filled; the pulmonary veins very full; the left auricle and ventricle empty; and the aorta contained a little blood. The trachea presented some bloody froth on opening, which was increased in quantity on pressing the lungs; the body of the cat was stiff, and the blood was coagulated in the large and small vessels and in the right side of the heart. The iris did not present any signs of irritability, nor was the sphincter ani relaxed.

Experiment XII.

The Points examined.

Effects of two minutes and a half immersion; Dissection.

To ascertain exactly the period of resuscitation after the shortest period of immersion, a half grown cat was immersed for two and a half minutes; it, however, did not recover, but remained without motion. The heart, on dissection, was motionless, supposed to be owing to violence of

the servant who submersed it, from a wound discovered in the lungs and the bloody water found near the heart; the peristaltic motion was vigorous, and the muscles retained their irritability, and the temperature of the cavity of the abdomen 96°; of the room 78°. The heat of the abdomen was examined three quarters of an hour afterwards, and was found to be 88°.

Experiment XIII.

The Points examined.

Effect of three minutes immersion; Dissection; Opening of the pericardium; Puncture of the cava.

That spontaneous resuscitation does not take place after three minutes, was proved by two other experiments: There was no motion after removal from the water after that period. Dissection.—The right auricle was at rest, excepting when irritated by the finger; the right ventricle moved slightly towards its lower end. The heart, on exposure to the air after the removal of the pericardium, retained its dark colour; the air had no effect upon the blood through the auricle or veins, though exposed for hours.

In one hour and fifteen minutes, motion in the ventricle still continued, as also in the auricle, on

irritation with the finger; the former moved more vigorously on opening the vena cava, from the removal of the distention; the blood was not coagulated. On puncturing the cava, the blood spouted to the height of one and a half inches. The auricle also lessened in size, but did not acquire the power of contraction spontaneously on opening the cava. The fact, then, is true, that distention of the cavities of the heart prevents their contraction. The contraction of the ventricle produces no pulsation on the pulmonary artery; the left side of the heart was motionless; the masses of coagulated blood which were found after its discharge from the cava, did not become scarlet as it generally does.

Experiment XIV.

The Points examined.

Effects of three minutes immersion; Puncture of the cava; Dissection; Heat.

The other cat mentioned in the above experiment, ceased to struggle violently and to rise directly upwards in fifty seconds, and when dissected, the blood was found coagulated in forty-eight minutes after death. The heart was motionless and did not return on puncturing the cava; the

veins of the tongue were moderately full; the cavæ, jugulars, and right auricle were filled with blood. The left auricle and ventricle were nearly empty, and the peristaltic motion had ceased. The temperature of the bowels, in eighty minutes after death, was 78°; of the room 68°.

Experiment XV.

A cat was immersed in water at the temperature of 60°, gradually cooling down to 45°, at which point it arrived in twenty minutes; in thirty minutes it had fallen to 42°, at which it continued during the whole experiment. The cat remained in the water for forty-five minutes, and the temperature of the interior of the abdomen was 75°. The muscles still retained their irritability on irritation with a knife; the heart was motionless, and the blood had coagulated in the cava and the heart; the disposition of the heart and blood-vessels was as usual; the thermometer stood at 80° in the room at the conclusion of the experiment.

Experiment XVI.

The Points examined.

Effect of submersion for five minutes; Circulation extinct; Water in the trachea; No circulation of the lungs from inflation; Puncture of the cava.

A cat was immersed for five minutes, and was opened immediately in order to discover the state of the circulation. The appearances on dissection were as formerly. The heart pulsated occasionally; the artery in the arm-pit was laid bare, but there was no pulsation in it, and scarcely any blood discharged from it on dividing it; the trachea was divided; water was found in it. The lungs were inflated about fifteen minutes after immersion, and the power of the heart increased; the quantity of blood, however, in the venæ cavæ or in the right auricle did not diminish; nor did the lungs become coloured, but exhibited a yellowish white appearance, showing clearly that no arterial blood passed through them. Puncture of the ascending cava caused great increase of motion in the right ventricle; it contracted more frequently, as also with more power, evidently produced by the removal of its distention, for pressure upon it caused the blood to flow through the puncture, so as to exhaust it completely

Experiment XVII.

The Points examined.

Puncture of the cava.

The same observations were repeated with regard to the puncture of the cava and with the same result.

Experiment XVIII.

Effect of 150° of Fahrenheit after submersion for four minutes; Blood; Heat; Puncture of the cava; Heart and Muscles.

A cat was drowned by submersion for four minutes. It was then exposed to a temperature of 150° of Fahrenheit; the limbs began to stiffen in fifteen minutes after immersion. After immersion, in seventeen minutes the fore-legs were quite stiff. As the resuscitation was hopeless, the dissection was made; in three minutes more the hind legs were stiff; the blood in the liver had not coagulated; the temperature of the interior of the abdomen was, thirty-five minutes after immersion, 104° of Fahrenheit; the heart had ceased; the vena cava was punctured; the blood effused coagulated in a very short time, so as to induce the idea that

the surface of the heart and lungs had some agency in effecting it. The heart did not move on puncturing it with the knife, or irritating it with the finger, and the aperture in the cava had no effect whatever in exciting it. The muscles had lost their irritability.

Experiment XIX.

The Points examined.

Effect of 124° of Fahrenheit after a submersion of four minutes; Heat; Irritability; Heart.

A very young kitten was submersed in water for four minutes, so far as to produce death without wetting the surface of the body. It was put into a temperature of 124° of Fahrenheit. It breathed twice after it was put into this increased temperature, but did not resuscitate. In twenty-four minutes the abdomen was opened and the temperature of its inside was 96°. In twenty-eight minutes after submersion the intestines had lost their irritability, as also the muscles; the heart had ceased to move on irritation with the knife, and on puncturing the cava the blood was fluid.

Experiment XX.

The Points examined.

Effects of immersion for four minutes and exposure to air of 111° of Fahrenheit; Heart; Heat; Peristaltic motion; Lungs; Inflation.

Another cat was submersed for four minutes and exposed to air of 111° of Fahrenheit's thermometer for twelve minutes. No symptoms of resuscitation appeared; it was removed and the heart was found to be motionless, except when irritated; it would then continue to move for some seconds spontaneously, and in twenty-five minutes the right ventricle had lost its irritability entirely, though the right auricle continued to move when irritated. The temperature of the abdomen was 102° after the intestines had lost their irritability, and also the muscles. The lungs were inflated at thirty minutes after immersion, and the power and motion of the right auricle was evidently increased; the pulmonary veins were evacuated, but the right side of the heart remained full of black blood; the artificial respiration was continued for a few minutes. After about ten minutes it was again repeated and the power of the heart was again increased; the left auricle was

empty; the heart contracted with more power. In a few minutes after, the contents of the right side of the heart, both of the auricle and ventricle, were pressed with the fingers into the pulmonary artery so as to exhaust their cavities, and then the inflation was commenced and continued for eight or ten respirations; the surface of the lungs was more red, and the left auricle was fuller, and the coronary arteries on the left side were evidently more red; the heart also resumed its power.

Experiment XXI.

The Points examined.

Effect of immersion for four minutes and exposure to 102° of Fahrenheit.

A young kitten was immersed for four minutes and placed in air of the temperature of 102° of Fahrenheit; it resuscitated gradually and in twenty-one minutes after immersion was perfectly restored. This proves that the temperature of 102° of Fahrenheit does not prevent resuscitation.

Experiment XXII.

The Points examined.

Effect of submersion for five minutes and exposure to a temperature of 100° of Fahrenheit; Heart; Puncture of the cava; Muscles; Peristaltic motion; Remarks.

The same kitten, in half an hour, was submersed for five minutes and placed in a temperature of 100°. If it recovered it would prove, in the most decided manner, the salutary qualities of this degree of temperature. It drew a convulsive breath immediately after being removed from the water, and another in two minutes after. The symptoms of resuscitation were again observed. The thermometer had fallen to 92° in the place where the cat was; at the end of eleven minutes to 90°; at the end of thirty-seven without any evidences of resuscitation. The cat was then opened. The right auricle and ventricle of the heart beat with some power; the left side had ceased to beat; the state of the parts was as before observed; the puncture of the vena cava evacuated the blood from the auricle and ventricle; the former was not increased in power; the latter considerably. The muscles had lost their irritability, and the peristaltic motion had ceased. As the immersion

in this case was for five minutes, it renders it probable that this temperature has no noxious qualities, for it is rare for this animal to stir after immersion for five minutes. The cases in which young kittens are used must be distinguished from those which are more advanced, as the former are drowned with more difficulty.

Experiment XXIII.

The Points examined.

Effect of air of the temperature of 134° after an immersion of four minutes. Dissection.

A kitten was submersed for five minutes, and exposed for fifteen minutes to air of a variable temperature, between 100° and 134°, without the least symptom of resuscitation. In fifteen minutes the limbs did not begin to grow stiff. It was opened; the heart was quiescent, except the right auricle; the peristaltic motion still continued; the blood was fluid, and the great blood-vessels about the heart in other respects as usual; the left auricle contained rather more blood than is common, being nearly full.

Experiment XXIV.

The Points examined.

Effect of immersion in an air of 120°.

A full grown cat was submersed for four minutes and exposed to a temperature of 120° for thirty-three minutes, and was then opened; the heart had ceased to beat; the muscles had lost their irritability; and the peristaltic motion had ceased. The symptoms of resuscitation appeared in this case. The state of the viscera showed an entire cessation of the powers of life in consequence of the application of this high degree of heat. The limbs, however, were not stiff, as in one of the former cases. The temperature of the interior of the abdomen was 106°.

Experiment XXV.

The Points examined.

Effects of submersion for five minutes, and of air at 100°. Dissection.

A kitten was submersed for five minutes in water and removed into air of the temperature of 100° of Fahrenheit, in which it remained for fifteen minutes without the least symptom of life.

It was removed and opened; the right auricle of the heart was found pulsating with vigour; the right ventricle had some slight motion, and the left side was quiescent; the veins and large blood-vessels were as usual; the peristaltic motion was vigorous. The result of this experiment proves that the temperature of 98° is more favourable to the continuance of the functions than those which are higher. The muscles had lost their irritability, and, in thirty minutes after immersion, in a temperature of 69°, the peristaltic motion of the bowels still continued; also the motion of the right auricle was occasional and strong.

Experiment XXVI.

The Points examined.

Effects of 64° of Fahrenheit on the heart, &c.

An old female cat was submersed in water at the temperature of 64° for three minutes and exposed to the open air. She ceased to struggle in one minute and a quarter, and did not move afterwards. On examination, in half an hour after immersion, the heart was motionless and the peristaltic motion of the intestines had ceased.

Experiment XXVII.

The Points examined.

Effects of 64° on the heart.

A young female cat about half grown was submersed in water at the temperature of 64° of Fahrenheit for four minutes and exposed to the open air of the same temperature. In two hours after, the heart still beat. The peristaltic motion ceased in half an hour. In twelve hours and a quarter the heart was examined, and I thought, on compressing the right auricle with the finger, that it gave a slight convulsive motion; but as it did not occur on repetition of the irritation, it was concluded that the irritability of the heart, if not entirely, was almost exhausted. On puncturing the superior cava the blood gradually flowed from the right auricle, and on pressing both the auricle and ventricle the blood flowed in a rapid stream, showing that the communication was easy between the auricle, ventricle, and veins, and that it would be possible to exhaust, by suction, from one of the jugulars, the cavities of the heart, and, of course, increase its power. In this instance, the puncture of the descending cava and the consequent exhaustion of the right side of the heart had no

effect in resuscitating its motions. They were perfectly quiescent. A clot of blood was found protruding through the puncture of the cava, which, when drawn out, evidently appeared to penetrate into the cavities of the heart. Much of the blood was still fluid, and I think the circulation might have been kept up, notwithstanding the coagulum. The colour of the blood, in the descending cava, was slightly red in its smaller branches.

Experiment XXVIII.

The Points examined.

Effects of five minutes submersion and 92° of Fahrenheit.

A very young kitten was submersed for five minutes and removed to a temperature of 92° Fahrenheit. It had scarcely been taken out of the water before it began to breathe. It was again immersed for almost one minute. It gradually recovered, but exhibited signs of uneasiness in the heated atmosphere.

Experiment XXIX.

The Points examined.

Effects of submersion for four minutes and 92° of Fahrenheit, and of air of 80°. Dissection.

Another half grown cat was submersed for four minutes and put into a temperature of 92° of Fahrenheit. It exhibited not the slightest symptoms of resuscitation after being removed to the heated air, but appeared perfectly dead. In thirty-five minutes after immersion the heart had ceased and did not move, even on irritating it with a knife; the peristaltic motion continued slightly; the blood was not coagulated; and the temperature of the interior of the abdomen was 87° of Fahrenheit.

Experiment XXX.

The Points examined.

Effect of air of 80° of Fahrenheit.

Another kitten was immersed for six minutes and exposed to 80° for one hour and twenty-three minutes, and then examined. The heart had ceased to beat, and also the peristaltic motion.

Experiment XXXI.

The Points examined.

Effects of submersion for six minutes and of 80° of Fahrenheit.

Another kitten of the same age was exposed in the same manner and under the same circumstances for one hour and twenty-three minutes. The heart had no motion except a little in the right auricle; the peristaltic motion had ceased; the blood had coagulated in the descending cava, though not in the heart. These two last kittens had been without food for eighteen hours. The thermometer was 80°.

Experiment XXXII.

The Points examined.

Submersion for six minutes; Effects of 82° of Fahrenheit; Dissection; Puncture of the cava.

Two other kittens of the same litter, which had not taken food for eighteen hours, were submersed for six minutes and exposed to a temperature of 82° for three quarters of an hour. The heart of one was pulsating; the right auricle moved with considerable vigour; the right ventricle moderately; the action of both the right auricle and

ventricle was increased by the puncture of the cava; the peristaltic motion continued in both kittens. The heart of the other had some considerable motion in the right auricle, but had lost its motion in the other cavities of this organ. At the end of fifty-five minutes after immersion, the right ventricle did not recover its beats when the cava was punctured. The veins near the heart were more empty in the young cats of this litter last experimented upon, after dissection, because they had breathed after immersion. The veins of the neck in the cats generally used in these experiments were not fuller than those in the axilla; a fact which shows that nothing like apoplexy takes place in submersion, for the whole venous system appears to be equally full.

Experiment XXXIII.

The Points examined.

Effects of 72° of Fahrenheit. Dissection.

A full grown cat, which had not eaten for twenty-four hours, was submersed for four minutes and exposed to the air of the heat of 72° for an hour. The right auricle of the heart still continued to move; the blood was, in some degree, coagulated, the heart being partially filled with

clots; the peristaltic motion and irritability of the muscles had ceased; the stomach contained a considerable quantity of water. In several, the irritability of the muscles remained for so short a time, that, in the last experiment, it has not been noticed. In this experiment the cat was in a debilitated state, as also in the six last preceding, so that the conclusion of the temperature being favourable to the support of life is strong.

Experiment XXXIV.

The Points examined.

Effect of 72° of Fahrenheit. Dissection.

A young kitten, which had been resuscitated and was much debilitated, was again submersed for seven and a half minutes; and after three quarters of an hour's exposure to the air of the temperature of 72° of Fahrenheit, the heart, the peristaltic motion, and the irritability of the muscles had ceased. It had not eaten for twenty-four hours. The stomach contained a considerable quantity of water.

Experiment XXXV.

The Points examined.

Effects of obstruction of circulation in the limbs on the power of the heart after submersion; Puncture of the vena cava; Blood; Heart; Diaphragm; Muscles.

A cat was strangled, and as soon as it had ceased to move its thorax was opened. The heart was found quiescent; of course the experiment failed. The lungs were natural, partially collapsed; and the venous trunks full of blood. A puncture in the descending cava evacuated the blood from the right auricle, yet caused no motion; the blood coagulated immediately on effusion from the vessels; the diaphragm moved on irritating the phrenic nerve; the heart had lost its irritability, and the muscles also: A circumstance which may have been produced by the excessive struggles of the animal which exhausted it.

By examining the humeral artery in the arm-pit in another animal, a few minutes after submersion, the heart still beating, the circulation was scarcely, if at all perceptible. To tie up the artery is therefore useless, as the circulation does not extend to the arm-pit, of course not to the thigh. It was postponed till, from the increase of

the power of the heart, produced by artificial inflation, the blood could be sent through the artery. The following experiments, then, are intended to examine the effect of various temperatures combined with inflation of atmospheric air as a means of exciting the power of the heart, preparatory to tying up the arteries, as a further auxiliary to strengthen the circulation.

Experiment XXXVI.

The Points examined.

Effects of submersion for eight minutes; Inflation for thirty-five minutes; Veins; Heart; Peristaltic motion; Heat of abdomen—of the room; Cavity of the pleura; Cause of difficulty.

A half grown cat was submersed for eight minutes. She was then withdrawn and the inflation of the lungs commenced at four minutes after immersion. The inflation was continued through the divided trachea for thirty-five minutes, when the thorax was opened. The descending cava was not so much distended with blood as usual; the veins in the arm-pit were also less distended, and some blood could be perceived in the axillary artery; the veins of the neck were considerably distended, though, perhaps, not quite so full as usual; the pulmonary veins were full of scarlet

blood, and the ascending cava appeared quite as full as it was generally; the two sides of the heart were pulsating with more force than in any other case hitherto examined; they continued to beat for an hour with considerable vigor, and when irritated, contracted strongly in all their cavities; the peristaltic motion was not perceptible in thirty-five minutes after immersion, and the temperature of the abdomen had fallen to 70° of Fahrenheit; the temperature of the air of the room was 61°; the heart continued to beat for ninety minutes after immersion with considerable vigor. In four and a half hours after, the whole right side still contracted, and also the left auricle when irritated; the lungs were found distended and coloured with scarlet blood, and what is very extraordinary, the pleura was filled with water tinged with blood, probably from the violence of inflation rupturing the lungs; there was some little water in the stomach, though probably it might have been there before the submersion. The discharge of the contents of the venæ cavæ and of the right side of the heart through the lungs appears to be the great obstacle. The pulmonary veins were filled with scarlet blood. It appeared that pulling the aorta excited the contractions of the heart.

Experiment XXXVII.

The Points examined.

Inflation after six minutes submersion; Dissection—Cavæ; Veins of the neck; Heart; Arteries; Heat; Peristaltic motion; Stomach; Muscles.

A cat about half grown was submersed for six minutes, and inflation was commenced in twelve minutes after immersion by introducing a gum elastic catheter into the trachea and attaching its extremity to the end of a common bellows. It was continued for thirty minutes, and, on opening the thorax, the right auricle was found slightly pulsating and very full of blood; the right ventricle had ceased, but was slightly excited by drawing the knife across it; the two cavæ were full, as also the veins in the neck and arm-pit; the pulmonary arteries were filled with scarlet blood; the left side of the heart was perfectly quiescent, not even to be moved by irritation with the knife; the arteries were almost entirely empty; the temperature of the abdomen was 75° of Fahrenheit at sixty-nine minutes after immersion; the peristaltic motion had ceased; the stomach contained no water; and the muscles had lost their irritability.

Experiment XXXVIII.

The Points examined.

Inflation after sixty-eight minutes immersion; Dissection—Heart; Peristaltic motion; Stomach; Heat; Veins; Left ventricle; Blood; Lungs; Puncture of the cava; Probe introduced into the heart through the jugular.

A full grown female cat was submersed for sixty-eight minutes, and then exposed for fifteen minutes on a table, and the inflation of the lungs was kept up by means of a pair of bellows and a gum elastic catheter introduced into the trachea for the space of thirty-five minutes. As no signs of resuscitation appeared it was conjectured that the attempt was vain. The body was opened; the right auricle and ventricle and the venæ cavæ were very full of black blood; also the veins of the neck, axilla, tongue, and ears; of course those of the inside of the head which was not opened; the heart was quiescent; the peristaltic motion had ceased; the muscles had lost their irritability; the stomach contained no water; and the temperature of the interior of the abdomen, in two hours after submersion, was 75°, when that of the room was 62°, a curious coincidence in the three last and fifteenth experiments in this respect; the pulmonary

veins appeared empty, but, on examination, were filled with scarlet blood, proving the effect of inflation; the left auricle contained little blood; the left ventricle very little; the blood was fluid; the lungs were of a scarlet colour. The puncture of the venæ cavæ produced no motion in the heart. A probe was run down the left jugular to the heart into the right ventricle, proving that the blood could be withdrawn by one of the branches of this vein, and thus the motion of the heart increased. It is, then, evident that atmospheric air alone, injected into the lungs, will not resuscitate these animals.

Experiment XXXIX.

The Points examined.

Effects of four minutes submersion; Inflation with atmospheric air and 70° of Fahrenheit; Dissection—Heart; Veins; Lungs; Arteries; Heat; Stomach; Muscles; Diaphragm.

A full grown cat was immersed for four minutes, as in the first of the three last experiments. It was found that simple inflation with the temperature of 60° did not recover the animal. Inflation was commenced in five minutes after immersion; the animal being put into a temperature of 70° and kept there for thirty minutes, the inflation being continued. The right side of the heart, as

also the left ventricle, still contracted; the two cavæ, the axillary veins, and the jugulars were still distended, though not quite so much as usual, nor was the right side of the heart quite so full; the lungs were very red, and the pulmonary veins were filled with scarlet blood; the carotids also contained more than usual. It was then evident that inflation and 70° had more effect, in this instance, than inflation and 60° had in the first of the three preceding experiments. The temperature of the abdomen was 82° in about one hour after immersion, which shows that there was also some gain in this respect. The stomach contained a small quantity of mucous glairy fluid. The muscles, when the animal was opened, about thirty-three or thirty-four minutes after death, had not lost their irritability, and the diaphragm also contracted on irritation.

Experiment XL.

The Points examined.

Effects of submersion for five minutes and the temperature of 80° with atmospheric inflation; Dissection—Veins; Heart; Arteries; Heat; Peristaltic motion; Blood; Danger of violent inflation; Power of the Heart; Blood coagulated.

A kitten was immersed for five minutes and exposed in a temperature of 80°, the lungs being inflated with a pair of simple bellows for thirty-three minutes. The body was then examined, and the heart was found pulsating in all its cavities, excepting the left auricle which was filled with dark-coloured blood; the pulmonary veins were scarlet.* On exposure to the air the power of the contractions increased; the two venæ cavæ, the jugulars, and the axillary vein were equally full as when no inflation was practised, but the artery in the axilla, the carotid, and the pulmonary artery were fuller than in the last case, shewing that there was more circulation, though it was very small, for on puncturing the carotid artery merely a drop issued forth, so that it was almost obliterated. The temperature of the abdomen inter-

* Shewing that no circulation took place between the lungs and left auricle.

nally was 80°; that of the room 71°. The peristaltic motion continued in a slight degree, and, in one hour after the inflation commenced, the blood, on opening the breast, was found coagulated. A sac of cellular membrane, as large as an egg, filled with air, with the back part of the peritoneum for its anterior coat, was found to occupy the back part of the abdomen from the pelvis to the diaphragm. It, no doubt, arose from violent inflation, which drove the air into the cellular membrane in the base of the lungs. The power of the heart then continues after clots have formed in the blood contained in its cavities. In this case the temperature of 80° of Fahrenheit appeared to be favorable.

Experiment XLI.

The Points examined.

Effect of condensation of air in the lungs.

A cat was submersed, and after some hours the lungs were injected by means of a syringe with some force. The air penetrated to the kidney on one side, surrounding it with a large bladder of air. The venæ cavæ were full of blood as usual, which convinced me that this means of condensing the air had no effect in evacuating the

cava, and thus assisting the passage of the blood through the lungs.

Experiment XLII.

The Points examined.

Effect of condensation of air in the lungs.

In another cat, in which the thorax was laid open, the whole surface of the lungs was evidently penetrated by the air, when pressed into them, rising from them like bubbles on the surface of mud; the surface of the pericardium about the thymus gland was also filled. The circulation had nearly ceased so that it was certain none had penetrated the arteries and veins, though, from its easy passage through the texture about the heart and of the lungs, it was evident that it would give easy admittance into them, provided the passage of blood through them had continued.

Experiment XLIII.

The Points examined.

Effect of seven and a half minutes immersion of 100° of Fahrenheit, and fifty-five minutes inflation with atmospheric air; Heart; Venæ Cavæ; Aorta; Humeral artery; Veins; Stomach; Lungs.

A cat, full grown, was submersed for seven and a half minutes, and a gum elastic catheter was introduced into the trachea, and at the end of eight minutes after immersion, and exposure in air of 100°, the lungs were inflated with atmospheric air for fifty-five minutes. The temperature of the air injected into the lungs was about 70°. At the end of fifty-five minutes the chest was opened and the heart beat with great vigor; the venæ cavæ were full of blood; the right auricle moderately distended; the right ventricle contained a considerable quantity of blood and was beating, though slowly, with considerable vigor; the left auricle was nearly empty of blood; the left auricle contracted with some vigor, yet, on dividing the aorta, its power was not sufficient to propel the blood through the aperture. It must, however, during the inflation, have had some effect in propelling the blood, for the humeral artery was

found to contain more blood than usual, and the veins in the axilla were very turgid; there was no water in the stomach, though the lungs were filled with froth, and the intercostal arteries with blood.

Experiment XLIV.

The Points examined.

Effect of 60° and ligatures on the extremities; Cavæ; Arteries; Heart; Heat; Stomach; Remarks; Veins of the abdomen.

A cat was submersed for five minutes, and removed into an air of 60° of Fahrenheit. The blood-vessels of the extremities were secured by ligatures, two round each whole extremity, and inflation with atmospheric air was continued for forty minutes; the two cavæ were filled with blood to, perhaps, a greater degree than usual; the arteries, however, were more full; the axillary artery and the carotid were evidently more distended; the former bled considerably on dividing it, which, in former cases, it never did; the lungs felt warm to the hand; and the heart still retained considerable power. The temperature of the abdomen was 73°; of the room 60°. This experiment was made under great disadvantages with regard to temperature, and yet the blood-vessels

were considerably filled; the right side of the heart, I also thought, was fuller of blood than common; the stomach was considerably distended. The animals had eaten some short time before death. The effect of the ligature, then, is considerable, even producing distention of the carotids, to which they were not applied. I thought, also, on examining the abdomen, that the mesenteric veins were fuller; the vena azygos was certainly more distended than usual.

Experiment XLV.

The Points examined.

Effects of immersion for nine minutes; Ligatures and inflation with atmospheric air for thirty minutes; Carotids; Axillary artery; Venæ cavæ.

A cat was submersed for nine minutes, and after tying the extremities with ligatures so as to compress the arteries, which occupied sixteen minutes, then inflating the lungs for thirty minutes, it was placed in an atmosphere of 110° for about fifteen minutes, and then in 100°. On examining the breast, the carotids were found much more filled with blood than in ordinary cases; the axillary artery also was partially full, and the corresponding vein nearly empty; the venæ cavæ were much less distended. The result of this experi-

ment convinced me that, assisted by ligatures, in the space of thirty minutes inflation, more effect was produced than by any other means yet tried. The motion of the heart was different from what is usual; it was of a steadily pressing character, as if it would be effectual in expelling its contents, which induced me to suppose, that to restore the power to the heart, it was necessary that the arteries should be in some measure full, otherwise the tension of the valves is not sufficient to prevent the passage of the blood from the left auricle to the left ventricle, and also the same is true of the pulmonary artery; it is necessary that it should be full; otherwise the blood passes backward from the right auricle into the venæ cavæ, and from the right ventricle into the right auricle; what effect would the experiment of injecting blood into the jugulars, so that it may be forced into the lungs, have upon the circulation? It is true that the distention of the right ventricle and auricle prevent their contraction, and the evacuation of the blood reproduces them, yet the invigoration produced by sending a large quantity of blood through the lungs may increase their power, and on the same principle inject into the arteries, the humeral for instance, so as to fill the aorta, carotids, &c. The left auricle contained scarlet

blood, but in a small quantity, and was very much contracted.

Experiment XLVI.

The Points examined.

Effects of submersion for thirty minutes; Of air of 110° of Fahrenheit, and inflation with atmospheric air for one hour, and ligatures on the extremities; Vena cava; Jugulars; Arteries; Carotids; Heart; Effect of loosening the artery; Heart; Effects of cold or air upon the heart; Blood coagulated.

A large female cat was immersed for half an hour, and removed to an air of the temperature of 110° of Fahrenheit. Ligatures were put around all the extremities but one. A pipe was introduced into the trachea and inflation was commenced in eight minutes after removal from the water and continued for one hour. The cat was then opened; the venæ cavæ were found very full of blood; the venæ azygos and the vein belonging to the internal mammary artery; the jugulars were as full as usual; the axillary artery and vein of the extremity which was not tied contained less blood than that on the opposite side which was tied; the carotid was fuller than usual; the heart was perfectly quiescent, as the axillary artery which was tied contained more blood than the one on the other side which was not, and also the

vein. It is clear that the ligature has an effect, though the result of this experiment was unfavourable to the complete resuscitation of the animal.

The cause of the axillary artery and vein in the side which was not tied having less blood than on the other side which was tied, was that it passed on to the lower parts of the extremity; for even after complete death, when the ligature around the other which was tied was loosened, the blood which was in considerable quantity on the side of the ligature towards the heart before opening it, immediately was sent along the artery to the parts below, which before loosening the ligature were perfectly empty; and the vein in the part beyond the ligature which laid alongside of it, which was very much distended, immediately contracted also and propelled its blood towards the heart, so that the artery which was considerably distended before was now, after loosening the ligature, almost empty, and the vein which was distended on the radial side of the ligature was more empty, and on the side of the ligature next the heart the vein was more full, proving clearly the great power which the arteries and veins have in propelling the blood, and that it requires only a little increase of the power of the heart to produce this effect. The cause of death, in this instance, is not easily understood; we should have suspected that there

would have been some remains of life in the heart, as afterwards really appeared to be; there are great anomalies in the progress of this disease. On removing the pericardium in about seventy-five minutes afterwards, the heart was examined, and the right auricle was found to contract on irritation, which it would not do immediately on opening the body, proving the effect of the air or temperature in exciting irritability. All the other parts of the viscus were perfectly quiescent. On opening the heart, clots were found in the cavities of both ventricles. The cat struggled greatly in dying.*

Experiment XLVII.

The Points examined.

Another cat was submersed and continued in the water for one hour and twenty minutes; in forty minutes more the ligatures were put upon the extremities and the inflation continued for one hour in a temperature varying from 100° to 110°, generally at 110°. At the end of this time the body was examined, and it was evident from the appearances of the carotids and aorta that there

* It is probable the high temperature of 110°, in which the cat was kept, prevented the continuance of the heart's motion.

had been some contractions of the heart, for they were full of blood, though not to distention, as also from the right auricle which still contracted on irritation. The axillary artery was also full on the side on which there was no ligature, and the vein on the same side quite full which shewed also some circulation. The artery on the other side, which was tied, was pretty full, but the vein comparatively empty. Does not this prove that the power of the heart must have driven the blood on through the axillary artery and forced the blood through the axillary vein to the heart? In the artery of the thigh there is very little blood, the ligature being put on just above the knee, so that it could not have obstructed it, as it did not extend so far down. These facts evidently prove that the limitation of the range of the circulation certainly increases the quantity of blood in those vessels which were free.

Experiment XLVIII.

The Points examined.

Effects of submersion; Heart; Electricity applied in a stream; Carotid and axillary artery; Cava; Remarks.

A full grown cat was submersed till it was dead. The heart, on examination, had ceased to beat, excepting the right auricle; electricity was

applied in a stream, the temperature of the room being 56° of Fahrenheit. Both the auricles soon began to contract vigorously, the ventricles being still quiescent. In the space of a few minutes they also began to contract and continued to beat vigorously for three quarters of an hour; the contractions were effectual and strong, because the blood in the carotid was considerable in quantity, and also in the axillary artery; they continued with great power from the influence of the electricity, for the heart was perfectly quiescent before; the effect, however, of emptying the cava was not very evident; the electricity was applied in a moderate stream, and it proved that the power of the heart was increased and sustained by it, as it had entirely ceased, excepting the right auricle.

Experiment XLIX.

Incomplete.

Another cat was submersed and exposed to the action of electricity, the shock being passed through its side; an error was committed in its application and the experiment failed.

Experiment L.

The Points examined.

Effects of electricity; Inflation with atmospheric air and opening the pericardium upon the heart; Effects of electricity and atmospheric air united; Temperature; Effect of electricity on the eighth pair of nerves; Effect of electricity after the heart had ceased to move; Inflation.

Another cat was submersed till it was dead, and ten minutes afterwards it was opened. The heart beat ten times in a minute in twenty-two minutes after immersion; in twenty-eight minutes after immersion a stream of electricity was sent through it, and continued for five minutes, and the heart beat only three times in a minute. Inflation of the lungs was made for ten minutes with no increase of power in the heart; the pericardium was opened and the surface of the heart exposed to the air after the irritability had apparently ceased, and the heart, in a minute longer, began to move, and its power gradually increased, the contractions appearing in all the ventricles; electricity and inflation were applied alternately, and it was evident with effect; the power of the heart was, in this instance, considerable, for the carotids and axillary artery contained considerable quantities of blood; the temperature of the

room was 56° of Fahrenheit; the stream of electricity was passed, as in the last instance, in about three quarters of an hour after immersion. Its effect was tried on the eighth pair of nerves by connecting with an iron hook introduced below the nerve with the machine, and sending the stream of electricity through the heart, the animal being placed on an insulated stool, but with no effect. After the contractions of the heart had nearly ceased, in ninety-five minutes after the immersion, its power was evidently increased, the whole organ contracting with considerable vigor. Inflation was then applied, and it was thought to increase its contractions.

Experiment LI.

The Points examined.

Heat after submersion; Effect of electricity on the heart; Effect of opening the pericardium on the heart; Effect of air and electricity externally applied to the heart.

A cat was killed by submersion and opened in ten minutes after immersion. The heart, in twenty-two minutes after immersion, beat fifteen times in a minute. In one hour and three minutes it had ceased. Electricity was applied, but without effect. The pericardium was opened, and the heart exposed to the air in seventy-nine minutes

after immersion, and it began immediately to contract with vigor, so that, in the last experiment, it was evident that the motions of the heart were occasioned by the contact of the air, as the pericardium was opened early in the experiment. The electricity was again applied; the heart exhibited contractions of increased vigor almost immediately, so the air and electricity combined increase the power of the heart after it had ceased from the action of electricity alone.

Experiment LII.

A CAT was submersed, and examined after fifteen minutes. On opening the thorax, the right auricle contracted feebly. It was left for twenty minutes longer, and the ventricle contracted somewhat, though scarcely perceptible. A bladder, filled with warm water at 120° of Fahrenheit, was approached to the heart; it had no effect whatever. The pericardium was opened, the heat of the room being about 60°. It shortly after contracted with vigor, and was more sensible to mechanical irritation. A wire heated red hot, applied to the eighth pair of nerves, excited no contractions in the heart; when in contact with the organ itself they were vigorous. The heart increased in power instantly, proving that the contact of the air had great effect.

Experiment LIII.

The Points examined.

Effect of submersion and 58° Fahrenheit, and exposure to the air in a diseased cat.

A cat was drowned in air of 58° of Fahrenheit, and in half an hour afterwards the arteries were found to be equally distended with blood, as in the four last experiments, particularly the carotid. So that it is a property of the animal, submersed in a temperature of 58°, to empty the arteries in a shorter time. It is certain that the electricity did not increase the volume of the arteries, as was conjectured from the last experiments. This cat had an inflammation of the thymus gland; it will, therefore, be necessary to repeat it. As far as this fact goes it is unquestionable that the arteries were fuller.

Experiment LIV.

The Points examined.

Effects of electricity drawn off by points on the heart—in a stream—by broad surfaces; Temperature of 58°; Effect of electricity by sparks; Effect of pericardium opened combined with electricity and imperfect inflation; Principle on which agitations of the extremities act, and pulling the carotid.

Two cats were submersed till they were dead, and in five minutes afterwards they were placed on an insulated stool, and one of them was exposed to a stream of electricity passed through both sides of the heart by points placed on each side of it, the thorax being opened to discover its motions. Its motions were not increased, but in ten minutes after its first application had ceased entirely, and in fifteen minutes was not irritable by the point of the knife. The other, through which the electricity was passed in a stream by two broader surfaces, was increased in frequency and in power; in fifteen minutes the heart also began to weaken; the stream was then applied and drawn off by broad surfaces from the first, and it was again resuscitated and its powers increased; the temperature was 58°. In both it was drawn off by sparks without increasing their power in the

least. The pericardia of both were then opened and exposed for ten minutes to the air, and the hearts were increased in frequency and in power; electricity was then drawn off from them by points and with the same effect. A stream of electricity was passed through them and it increased them still more. It was now an hour since they were submersed, and as both the hearts were beginning to decline, the lungs of one were inflated, but as they had weakened very considerably it was soon omitted. To ascertain whether any stimulus might be communicated to the heart by agitating the extremities, as it was conjectured that the only mode in which an effect could be produced by that means was by stretching the arteries; the axillary artery was laid bare and pulled; the motions of the heart were evidently increased still more by pulling the carotid from its more immediate connection with the heart; electricity was passed through the stomach without effect.

Experiment LV.

The Points examined.

Effect of electricity in resolving coagulations by points and by a stream; Also on the colour of the clot.

A clot of blood of the size of a hazle-nut was laid upon a glass stand and electricity was drawn through it by points for fifteen minutes without the effect of dissolving it. A stream was then passed through it and with the same result. I conjectured, in the last case, some little fluid appeared about the clot, but this was not concurred in by the gentleman who assisted me. The parts of the clot, when the sparks were drawn off, was certainly more red than those which were more removed. This might have been accidental.

Experiment LVI.

The Points examined.

Effect of heated air of 160° of Fahrenheit on the animal system; On the temperature of the abdomen; Convulsions; Final recovery.

A cat was exposed to air of the temperature of 160° Fahrenheit and removed at the end of four minutes; convulsions were the consequence, and

the thermometer, in the abdomen, rose to 106° in twenty minutes after. The object of the experiment was to ascertain whether the temperature of the interior of the body actually rose in consequence of the application of heat externally, and, of course, whether a temperature incompatible with life was thus generated. After the convulsions of the animal ceased, the respirations were panting and frequent beyond measure. In the course of thirty minutes after its removal it had entirely recovered and appeared to be strong.

Experiment LVII.

The Points examined.

Effect of submersion and time on the emptying of the cava.

Two cats were submersed at five minutes after five, P. M. and left till next morning to ascertain whether there was any probability in the extraordinary facts related of submersion for a long period, and whether, as Harvey had observed, the vena cava and right side of the heart would be more empty of blood, which presents so great an obstacle to resuscitation. One in twenty-three, the other in twenty-four hours was opened and exhibited the following appearances: the venæ cavæ were full, and the arteries contained some

blood; the heart was without irritability on the application of mechanical stimuli, or from the admission of air into the pericardium, proving clearly that the changes which appeared in Harvey's experiment do not take place in the unopened body, and that the irritability did not remain in the heart, &c.; the thermometer ranged between 50° and 60° of Fahrenheit.

Experiment LVIII.

The Points examined.

Effect of submersion on the cava, pulmonary veins, heart, carotid, and axillary artery; Exposure of the heart and pulling of the carotid.

Another cat was submersed till it was dead, and laid in the air varying between 50° and 60° of Fahrenheit, and was opened at the end of thirteen hours. The venæ cavæ and right auricle were much distended with blood; the ventricle was not so much so; the pulmonary veins were full of black blood, and the left auricle contained more blood than usual; the left ventricle was much as before; the carotid and axillary arteries contained more blood than is generally found in dissected animals when the thermometer ranged between 70° and 80°; the exposure of the heart to

the air, by opening the pericardium and pulling the carotids, produced no contractions; of course, the irritability had irrevocably gone.

Experiment LIX.

The Points examined.

Effect of submersion and time on the heart and vessels, and of opening the pericardium.

Another cat, which had been submersed at the same time, was examined after fourteen hours immersion in water, the temperature of which ranged between 50° and 60° of Fahrenheit, and it was found to exhibit the same appearances. The heart and vessels were in the same state, and the former did not contract on exposure to the air by opening the pericardium or on pulling the carotids; the right auricle and ventricle were, perhaps, more soft than in the last instance. These experiments prove that Harvey's observation does not always hold good, and that the irritability is exhausted in thirteen or fourteen hours.

Experiment LX.

The Points examined.

Effect of heated fluids on the heart when injected into the stomach; Heart; No sympathy between the stomach and the heart.

A cat was submersed till all signs of life had ceased. The thorax was opened previous to the injection, when the heart was beginning to decline in power; two ounces of spirits of turpentine, milk warm, were then injected into the stomach, but with no effect on the motions of the heart. This experiment was performed under the idea that there was a sympathy in the stomach with the heart, as there exists between the lungs and the heart. This organ declined gradually without being the least influenced by the injection.

Experiment LXI.

The Points examined.

Effect of inflation and temperature milk warm, and hot water on the heart when injected into the stomach.

The above experiment was repeated, and inflation was combined with it. The heart went on notwithstanding, but regularly weakened; the in-

flation was omitted after a short time; the injection produced no effect upon the heart. Upon another animal very hot water was injected. From the effect which this agent produces in hysteria and other nervous diseases it was hoped that its influence would be favourable; but without any effect whatever.

Experiment LXII.

The Points examined.

Effect of submersion; Heart quiescent; Electricity passed through the stomach; No sympathy between the heart and the stomach evinced by electricity.

A cat was submersed till it was dead, and on opening the thorax the heart was quiescent. A stream of electricity was passed through the stomach by means of a gum elastic catheter with a wire concealed in it, introduced into that organ. The electricity was conducted through it by placing a brass rod with a knotted end on the outside of it, and thus passing a stream through it, the animal being placed on an insulated stool connected by the metallic conductors with the ground and the machine. No effect was produced by continuing the process for five minutes; no sympathy, then, existed between the stomach and the heart, as evinced by electricity. The pericardium was

opened, and the heart, in a short time, began to contract from exposure to the air, and on passing a stream of electricity through it, it became vigorous.

Experiment LXIII.

The Points examined.

Effect of the surface of the lungs and heart on coagulation

Some blood was permitted to fall upon the surface of a board on which a cat prepared for experiment laid, and at the same time blood was also discharged on the surface of the lungs and heart; the latter coagulated immediately, whilst the former did not during the time the experiments lasted, proving the wisdom of nature in establishing this quality to prevent the mischievous effects of wounds of the heart and lungs.

THE END.